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#14 Appeal Brief
1/21/04
J. N. Fant

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| In the Application of: | | |
| M. ANTHONY STONE, ET AL. | | |
| on | HONEYCOMB REMOVAL | Examiner: C. Goodman |
| Serial No.: | 08/327,744 | Art Unit: 3204 |
| Filed: | October 24, 1994 | (Our Docket No. 3309P-65) |

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## APPELLANTS' APPEAL BRIEF

Dear Sir:

This appeal is taken from the final rejection dated October 6, 2003 in which Claims 1-8 were rejected under 35 U.S.C. § 103(a) as being unpatentable over the Applicant's background text, McComas (U.S. Patent No. 5,167,721) and Carr (U.S. Patent No. 4,731,125). Also, claims 1-8 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Shiembob, Ryan or Ackerman (U.S. Patent Nos. 4,433,845, 4,409,054, and 4,218,066 respectively) in view of McComas (U.S. Patent No. 5,167,721) and Carr (U.S. Patent No. 4,731,125).

## Real Party In Interest

The real party in interest in the above-referenced application is:

Pratt & Whitney Advanced Systems Technologies, Inc.
(formerly WATERJET SYSTEMS, INC.)
Huntsville, Alabama 35807



## Related Appeals and Interferences

This case, now pending for over nine (9) years, was the subject of a decision of Board of Patent Appeals and Interferences February 20, 2003. The Board did not sustain the Examiner's rejection and remanded the case back to the Examiner for further consideration. The Examiner issued an Office Action on May 7, 2003 rejecting all of the pending claims. An Amendment and Response was filed by the Applicants on August 7, 2003 and the Examiner finally rejected the claims in an Office Action dated October 6, 2003.

There are no other related appeals or interferences of which Appellants are aware regarding the above-referenced application.

## Status of the Claims

Claims 1-8 are pending in this application. (A copy of the claims as finally rejected is attached as Exhibit A.) Claims 1-8 stand rejected by the Examiner under 35 U.S.C. § 103 and are presented to the Board in this Appeal.

## Status of Amendments

Subsequent to the Board's February 20, 2003 decision, an Amendment dated August 7, 2003 has been entered in the case.

## Summary of the Invention

With reference to Fig. 1 and page 7, line 29 - page 8, line 2 of the specification, the present invention is directed to the removal of metal honeycomb 1 and associated

braze from a substrate 3 using high pressure liquids. The metal honeycomb has a base and a ribbon direction 1a, and is typically fixed to the substrate by braze.

The method comprises directing a pressurized liquid at an angle Ø of less than about 90° between the liquid and the substrate 3, e.g., the liquid travels in a direction that is *not* perpendicular to the surface of the substrate. The liquid is directed through at least one orifice of a nozzle 5 such that the liquid forms a liquid stream 7 upon exiting the nozzle. The liquid stream 7 is directed to strike the substrate 3 at the base of the honeycomb 1, and remove the honeycomb and associated braze from the substrate.

Various prior art methods exist for removing honeycomb from a substrate. Conventional methods are substantially limited to machining and grinding techniques, chemical immersion and de-brazing using heat. These methods often have undesirable results such as irreparable damage to the substrate, thus rendering the substrate unsuitable for re-use.

In contrast, the novel method of the present invention utilizes a pressurized liquid stream directed to strike the substrate at the honeycomb base, where the honeycomb joins the substrate. In this manner, the liquid stream removes the honeycomb and braze from the substrate without damaging the substrate, such that the substrate can be re-used.

## Issues

Did the Examiner err in concluding that, under 35 U.S.C. § 103(a), Claims 1-8 are unpatentable over Applicant's background text, McComas (Exhibit B) and Carr, (Exhibit C) and, conversely, over Shiembob (Exhibit D), Ryan (Exhibit E) or Ackerman (Exhibit F) in view of McComas and Carr.

## Grouping of the Claims

Claim 1 is independent; claims 2-8 depend directly upon claim 1. Claims 1-8 stand or fall together.

## Background:

As mentioned above, the present case has been pending for nine years. Previously, the Examiner issued a final office action that the Applicant appealed to the Board of Patent Appeals and Interferences (the "Board"). The Board concluded that the Examiner's grounds of rejection were improper and remanded the case to the Examiner for further consideration. The Examiner has once again issued a final office action in the present case. The Examiner, however, has presented essentially the same rejection that the Board found untenable in its first decision. As such, the Applicant now appeals the Examiner's second final rejection as argued below.

Set forth below is a summary of the previous final Office Action, the Board's prior decision as compared with the current final Office Action; the subject of this Appeal. In essence, the Board overturned the rejections from the previous final Office Action noting the shortcomings of the applied references. In the current final Office Action, however, the Examiner has repackaged the exact same references with a new reference from non-analogous art whose teachings are less material than those already applied by the Examiner in formulating the previous rejections that were not sustained by the Board.

*The Previous August 15, 2000 Final Office Action:*

The Examiner issued a final Office Action dated August 15, 2000, (the "2000 Office Action.) (Exhibit G). In the Office Action, the Examiner rejected Claims 1-8 under 35 U.S.C. § 103(a) in view of the combination of McComas (U.S. Patent No. 5,167,721), Ryan (U.S. Patent No. 4,409,054), Ackerman (U.S. Patent No. 4,218,066) and/or Shiembob (U.S. Patent No. 4,433,845).

In the 2000 Office Action, the Examiner states that although McComas lacks a honeycomb as the form of the coating, McComas teaches that the disclosed method encompasses removal of abradable seals which are used in gas turbine engines. The Examiner further states that regarding the honeycomb, Shiembob, Ryan, and Ackerman all teach that a honeycomb, braze and substrate are well known abradable seals in the art for gas turbine engines. Therefore, it would

have been obvious to the ordinary artisan at the time of the instant invention to provide the method of McComas with the honeycomb as taught by either Shiembob, Ryan or Ackerman in order to facilitate the removal of the honeycomb from the substrate during maintenance.

*The Applicant's previous arguments to the Board regarding the 2000 Office Action.*

As successfully argued to the board, the Examiner failed to establish a *prima facie* case of obviousness in accordance with MPEP §§ 2142 and 2143 through the combination of McComas, Ryan, Ackerman and/or Shiembob. The cited references contain no suggestion or motivation to modify the reference or to combine the reference teachings. Moreover, the suggestion or motivation to combine the references cannot be found in knowledge generally available to one of ordinary skill in the art.

The teachings of Schiembob, Ryan, Ackermann and McComas have been discussed at length in numerous papers during the prosecution of the present case and are summarized below.

McComas is directed to a method for removal of coating materials, and in particular the removal of abradable, wear resistant, and thermal barrier coating materials which have been applied by either sintering powders or fibers, or by plasma spraying, utilizing liquid jet erosion.

In Ryan honeycomb structures, such as those used in turbine engine abradable seals, are provided with a uniform density filling of a suitable abradable material. The abradable material is prepared as a tape preform using an organic binder. The preform is forced into the honeycomb using a rubber tool.

Ackerman is directed to an apparatus for impeding the leakage of a gaseous medium between rotating and stationary components of a gas turbine engine. Wide channel sealing techniques are discussed in combination with honeycomb facing materials.

Shiembob is directed to the manufacture of a seal for a row of turbine blades in which the seal is a honeycomb seal and a layer of insulation is positioned in the cells of the honeycomb by flame spraying. A process for accomplishing the deposition of the insulation is also described.

Specifically, contrary to the Examiner's statement that *"the honeycomb is another form of an abradable seal that is a "coating" for which McComas method is to be applied"*, the lack of any reference whatsoever to honeycomb in the McComas patent, points to the conclusion that it would *not* have been obvious - even to those highly skilled in the art. McComas is directed to "the removal of coating materials, and specifically to the removal of abradable, wear resistant, and thermal barrier coating materials which have been applied by either sintering powder or fibers, or by plasma spraying, utilizing liquid jet erosion." See Technical Field McComas, Col. 1, line 10. A honeycomb structure is *not* such a coating, as was well known by those skilled in the art at United Technologies Corporation. Likewise there is no teaching or suggestion in Shiembob, Ryan or Ackerman relevant to honeycomb removal.

Moreover, there was no reasonable expectation of success as honeycomb has very different erosion characteristics from the sprayed and sintered coatings discussed in McComas. The methods typically employed to remove sprayed and sintered coatings such as plasma, rubber, fibermetal and epoxy materials from base materials such as nickel, steel, titanium, and aluminum are *not* generally applicable to honeycomb removal.

Finally, the cited references do not teach or suggest all of the claim limitations. No combination of the cited references teach or suggest positioning the pressurized liquid to strike the substrate at the base of the honeycomb as in claim 1 of the present invention. In McComas, the liquid stream is directed towards and impinges on the *topmost, exposed surface* of the non-honeycomb coating, not the substrate (FIG. 1). Accordingly, McComas teaches away from the invention as defined in claim 1, in which a liquid stream strikes *the substrate* at the base of the honeycomb. Furthermore, neither Shiembob, Ryan or Ackerman make any reference whatsoever to removing

honeycomb from a substrate by any process, let alone a process in which a "... *liquid stream strike[s] the substrate at the base of the metal honeycomb*" as claimed in the present application.

*The Board's Prior Decision:*

The Board did not sustain the rejection of the claims under 35 U.S.C. § 103(a). The Board held that the combined teachings of the prior art applied by the Examiner would only suggest that one of ordinary skill in the art of removing honeycomb and braze from a substrate would have done so by directing a liquid stream at the top of the honeycomb until the braze is exposed, as set forth by McComas. As the Board noted, the deficiency in the Examiner's rejection was the lack of any suggestion in the applied prior art for the recitation as set forth in Claim 1 of the liquid stream "striking the substrate at the base of the honeycomb." Indeed, the Board noted that only the Applicant's disclosure, and not the applied prior art of record, taught or would have suggested of the liquid stream striking a substrate at the base of the honeycomb. A copy of the Board's Decision is attached as Exhibit H.

## Discussion

The Examiner has reopened prosecution in this case as a result of the Board's decision of February 20, 2003 and the remand set forth therein. The Examiner has set forth new grounds for rejection in a final Office Action dated October 6, 2003. (Exhibit I). The Examiner now relies on a combination of the foregoing references deemed by the Board to be insufficient in its Decision of February 20, 2003 together with U.S. Patent No. 4,731,125 to Carr to formulate the present rejection. Carr, however, lacks any reference to the step deemed lacking in the Examiner's combination of references the Board previously determined to be inadequate.

Specifically, claims 1-8 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over the prior art as set forth in the specification, page 1, lines 8-28 and in view of McComas et al. and Carr. Thereafter, claims 1-8 have been rejected by the

Examiner under 35 U.S.C. § 103(a) as being unpatentable over Schiembob, Ryan or Ackermann in view of McComas et al. and Carr.

The Examiner's newly added reference, Carr, is non-analogous art and lacks any reference to the step deemed lacking in the Examiner's combination of references the Board previously determined to be inadequate. Specifically, Carr when combined with the cited references does not teach or suggest a liquid stream striking a substrate at the base of the honeycomb.

The new reference Carr discloses a method for blast cleaning paint and other adhesive coatings from composite surfaces formed from a reinforced matrix material. A special soft media is used at a relative low pressure to prevent damage to the soft composite material. A preferred method calls for the use of the media having a Mohs scale hardness number of 3.0 or less. The media is pressurized to approximately 40 psi and directed at the composite surface to be cleaned.

It is instructive to review the substance of the Board's February 20 decision. In that opinion, the references that were applied by the Examiner were the same references cited above, but for the addition of Carr. In sum, claims 1-8 stood rejected by the Examiner under 35 U.S.C. §103(a) as being unpatentable by McComas in view of Schiembob, Ryan or Ackermann. They were also rejected on the same grounds as being unpatentable over Schiembob, Ryan or Ackermann in view of McComas.

As discussed above, the Board did not sustain the rejection of the claims under 35 U.S.C. § 103(a) on either grounds. The Board held that the combined teachings of the prior art applied by the Examiner would only suggest that one of ordinary skill in the art of removing honeycomb and braze from a substrate would have done so by directing a liquid stream at the top of the honeycomb until the braze is exposed, as set forth by McComas. As the Board noted, the deficiency in the Examiner's rejection was the lack of any suggestion in the applied prior art for the recitation as set forth in Claim 1 of the liquid stream "striking the substrate at the base of the honeycomb". Indeed, the Board noted that only the Applicant's disclosure, and not the applied prior art of record,

taught or would have suggested of the liquid stream striking a substrate at the base of the honeycomb.

The Examiner now has applied the same references in the same manner as previously rejected by the Board, but now augments these references with Carr. Carr, however, for the reasons stated below, is not analogous art and whose technical field, parameter ranges and thrust of teaching is well outside of those of the references of record. Moreover, Carr lacks any reference to the step deemed lacking in the Examiner's combination of references the Board previously determined to be inadequate

As an initial matter, Carr represents a clear case of non-analogous art. As is known by the Examiner, a reference must be considered as a whole, for all that it teaches. When viewed in its entirely, the problem that Carr addresses and the technology used by Carr to solve its problem are far removed from that of the other combined references, and certainly the present invention. One skilled in the art of honeycomb removal brazed onto jet engine turbine blades would simply not look to paint removal schemes for guidance. Secondly, even if Carr may be combined with the references of record, its teachings fail to provide any additional suggestion of the present invention. Carr provides no new teachings when compared with McComas.

Unlike the present invention and cited references, Carr discloses a method directed to the removal of paint while avoiding damage to soft substrate like composites. See col. 2, l 4-6. In fact, Carr is titled "Media Blast Paint Removal System". Consequently, unlike the present invention, the Carr method is for removing soft homogenous materials, like paint, that are not robustly fastened to the surface of an easily damaged substrate.

Additionally, the Carr method utilizes blast media to remove paint, as opposed to a fluid stream as in the present invention, so the choice of blast media is critical, (see col. 3, lines 16-17). Significantly, the stream itself contributes nothing to the removal

process. In Carr, the particles used for the paint removal are preferably entrained in an air stream generated by a pneumatic sand blaster (col. 3, line 47).

Moreover, Carr steers those skilled in the art further away from the present invention by distinguishing his method from conventional sand or bead blasting techniques in urging the use of *lower* pressures than are utilized in these known processes. See col. 3, line 54). In sharp contrast to the present invention, Carr suggests an extremely low pressure of only 40 lbs. per square inch at the nozzle to avoid substrate damage. By the time the stream strikes the surface, the pressure has dropped substantially, and paint removal is accomplished by the impact of the beads on the paint.

Unlike the present invention and cited references, Carr discloses a media fluid stream presented to the work piece at an angle from the vertical. The reason for the inclusion an angle in the presentation of the air stream and media is, as noted in column 4, to avoid putting excessive force into the surface of the composite, and thereby cause substrate damage. See lines 47-50. In addition, a non-vertical angle allows larger numbers of entrained media particles to strike broader areas of paint since a greater surface area is presented (by simple geometry) to the media stream. See Carr, col. 4, lines 64 et seq. As such, the Carr is nonanalogous art and may not be combined with the cited references and applied to the present invention.

Furthermore, any attempt to combine the teachings of Carr with the teachings of McComas et al. would be either ineffective, destructive or both. Inclusion of soft glass beads into the present water jet would be completely ineffective at the pressures and with the materials sought to be removed by McComas and that of the present invention. Media and the use of the fluid pressures taught by the present invention with the composite structures of Carr would simply result in the obliteration of the composite. The adjustment of the angle of the glass bead stream in Carr is to ensure that minimal energy is put into the substrate surface itself. With the present invention, however, the angle must be selected to effectively attack in a highly focused way the very base of the honeycomb, two entirely different technical considerations. In light of

the above, Carr is clearly non-analogous art and teaches away from the present invention.

Additionally and significantly, even if Carr is combinable with the previously cited references, Carr does not teach or suggest a liquid stream striking a substrate at the base of the honeycomb. As disclosed, the Carr method is limited to a general, unfocused presentation of the media stream to a painted surface, with the only criticality noted being the need to avoid the presentation of media to the cleaned surface (and thereby avoiding damage). The relevant text in Carr on this point is found at col. 3, lines 52-55 which state "[t]his is generally done by angling away from a perpendicular direction the media flow with respect to the target surface *so that the leading edge of the coating* being removed is exposed to the force of the media flow." (emphasis added).

The "edge" referred to by Carr is the boundary line between the painted and cleaned areas on the target. No reference of any kind is made to the substrate/layer interface. Fig. 2 is consistent with this interpretation, as is the claim language. Note the air stream (plus media) in Fig. 2 is presented only *generally* to the area requiring paint removal and the adjacent clean surface, encompassing portions of the top surface of paint as well as the just-cleaned target. The claims also support this understanding – not a singly claim refers to an "edge" or any characteristic thereof.

Carr specifically teaches that the best method of cleaning is to direct the media flow primarily at areas of paint and, as part of the process, redirect the media flow to other unremoved areas whenever removal in the first area has been substantially accomplished. See Carr, col. 5, lines 3, et seq. In this way, "exposure of cleaned and therefore unprotected composite surface to the full force of the media blast is minimized". Also, Carr claims his method will remove only one of a plurality of layers from an area, leaving the inner layer(s) and substrate intact. See Carr, col. 5, lines 33-36.

There is no mention in Carr of a "painted surface – cleaned substrate interface" or of any importance thereof in the cleaning process, because it is of no particular import

in a paint removal application. It is only in the present technical context, metal honeycomb brazed to a metal substrate, does this interface becomes important since the non-homogenous braze – honeycomb structure to be removed presents a unique set of technical parameters, and honeycomb braze removal by a liquid jet was not attempted previously. Not surprisingly, there is no recognition in Carr of directing the stream to the "substrate at the base of the honeycomb" as in claim 1 of the present invention.

In the present method, the pressures of the fluid sufficient to remove honeycomb and braze without damaging the underlying dense metal substrate need to be extreme. Also the present method intrinsically requires a very high-pressure liquid jet whose pressures are in the range of *tens of thousands* of pounds per square inch, many orders of magnitude beyond the pressure range taught by Carr. Secondly, there is no media used with the present method. The liquid stream alone attacks the honeycomb seal where it is adhered to the substrate surface; that is at the braze-seal intersection, without cutting into the substrate.

Carr provides neither new technical content nor impetus towards the present invention. In that respect, Carr is less material than the previously applied references, especially McComas. The substrate and pressures taught by McComas are much closer technically to the present application than Carr, as is the discussion of angular presentation of the jet. McComas is therefore cumulative of Carr.

In sum, the teachings of McComas et al. taken together with Schiembob, Ryan or Ackermann in view of McComas et al. have been dealt with unambiguously by the Board in the February 20 decision and have been found to be deficient in providing a sound evidentiary basis for concluding the claimed method to be obvious. The Examiner has added Carr, which on its face is not analogous art, and which by itself or in combination with the cited references fails to hint or suggest the key step of presenting the liquid stream at the base of the honeycomb. Carr is clearly less material that McComas. As Carr lacks any reference to the step deemed lacking in the Examiner's combination of references the Board previously determined to be

inadequate, the present rejection is no more than duplicative of the rejection not sustained in the Decision of February 20, 2003. It should considered deficient again. Applicants request the Board allow the pending claims and, at long last, pass this case to issue. Early notice of the same is respectfully requested.

## Conclusion

In view of the foregoing, Appellants request that the Board reverse the Examiner's rejection of claim 1. Since claims 2-8 depend from claim 1 and include all of the limitations of this claim, claims 2-8 are patentable over the McComas and reference for at least the same reasons discussed above in connection with claim 1. Accordingly, Appellants also request that the Board reverse the Examiner's rejection of dependent claims 2-8.

The fee of $310.00 required under 37 C.F.R. §1.17(c) for submission of this Appeal Brief is enclosed. Please charge any deficiency in fee associated with the Petition and Appeal Brief to our Deposit Account No. 13-0235.

Appellants' Appeal Brief is being filed in triplicate.

Favorable consideration is respectfully requested.

Respectfully submitted,

By ______________________

J. Kevin Grogan, Esq.
Attorney for Applicants
Registration No. 31,961

McCORMICK, PAULDING & HUBER LLP
CityPlace II
185 Asylum Street
Hartford, Connecticut 06103-4102
Tel. (860) 549-5290
Fax. (413) 733-4543

## PENDING CLAIMS

1. A method for removing metal honeycomb and braze from a substrate, said honeycomb having a base and a ribbon direction, comprising: directing a pressurized liquid at an angle of less than about 90° between the liquid and the substrate, through at least one orifice of a nozzle such that the liquid forms a liquid stream upon exiting the nozzle, the liquid stream striking the substrate at the base of the honeycomb, thereby removing the honeycomb and braze from the substrate, whereby the substrate may be reused.

2. A method as in Claim 1 further comprising the step of forming a laminar liquid flow out of the nozzle, wherein said nozzle has an orifice and a bore which connects said orifice to a liquid supply, with said bore having sufficient length such that a flow of liquid from said liquid supply attains a laminar flow prior to exiting said orifice.

3. A method as in Claim 1 wherein the pressure of the liquid stream is above about 20,000 psi (about 1379 bar).

4. A method of Claim 1 wherein the pressure of the liquid stream is above about 30,000 psi (about 2068 bar).

5. A method of Claim 1 wherein the pressure of the liquid stream is above 35,000 psi (about 2413 bar) to about 60,000 psi (about 4137 bar).

6. A method as in Claim 1 wherein said angle is about 35° to about 65°.

7. A method as in Claim 1 wherein said angle is about 40° to about 60°.

8. A method as in Claim 1 wherein said liquid stream strikes the base of the honeycomb in the ribbon direction.

US005167721A

# United States Patent [19]

McComas et al.

[11] Patent Number: 5,167,721

[45] Date of Patent: Dec. 1, 1992

[54] LIQUID JET REMOVAL OF PLASMA SPRAYED AND SINTERED

[75] Inventors: Charles C. McComas, Palm City; John W. Appleby, Jr., Palm Beach Gardens; Gerard A. Sileo, Royal Palm Beach, all of Fla.; Herbert R. Barringer, Midwest City; Michael J. Patry, Oklahoma City, both of Okla.

[73] Assignee: United Technologies Corporation, Hartford, Conn.

[21] Appl. No.: 784,625

[22] Filed: Dec. 5, 1991

Related U.S. Application Data

[63] Continuation of Ser. No. 441,666, Nov. 27, 1989, abandoned.

[51] Int. Cl.[5] .......... B08B 3/02

[52] U.S. Cl. .......... 134/32; 134/34; 134/38

[58] Field of Search .......... 134/2, 22.12, 22.18, 134/24, 32, 34, 38, 40

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OTHER PUBLICATIONS

New Zealand Patent No. 176547 dated Feb. 1977 claims 1-10 and FIGS. 1 and 2 only.

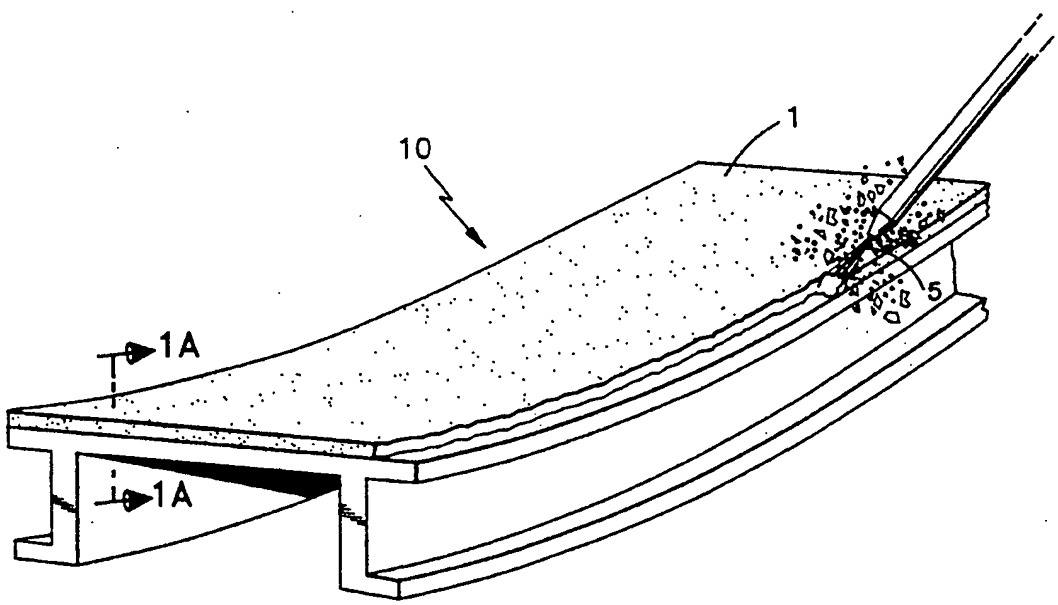
New Zealand Patent No. 173992 dated Mar. 1976 claims 1-20 and FIGS. 1-3 only.

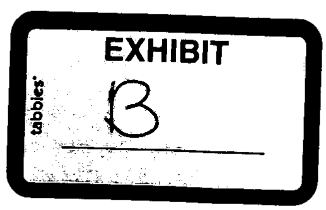
*Primary Examiner*—Theodore Morris
*Assistant Examiner*—Saeed Chaudhry
*Attorney, Agent, or Firm*—Pamela J. Curbelo

[57] ABSTRACT

Gas turbine engine coatings must often be removed during engine maintenance and repair. The techniques utilized to accomplish this task, machining, chemical stripping, machining followed by chemical stripping, or grit blasting, frequently result in component damage or destruction. Liquid jet erosion can be utilized to remove seals, coatings, or portions thereof without damaging the engine hardware.

13 Claims, 2 Drawing Sheets



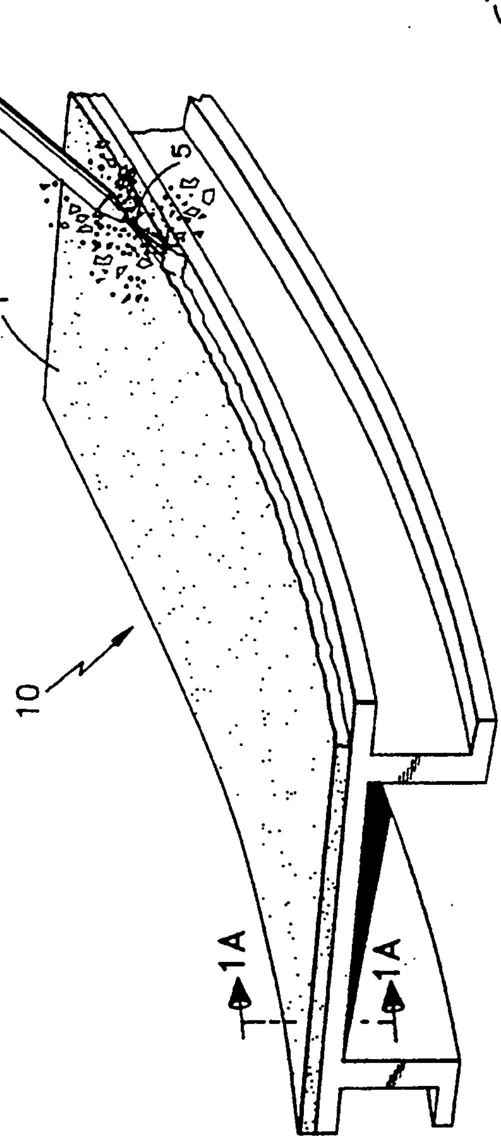



FIG.1

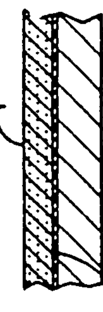
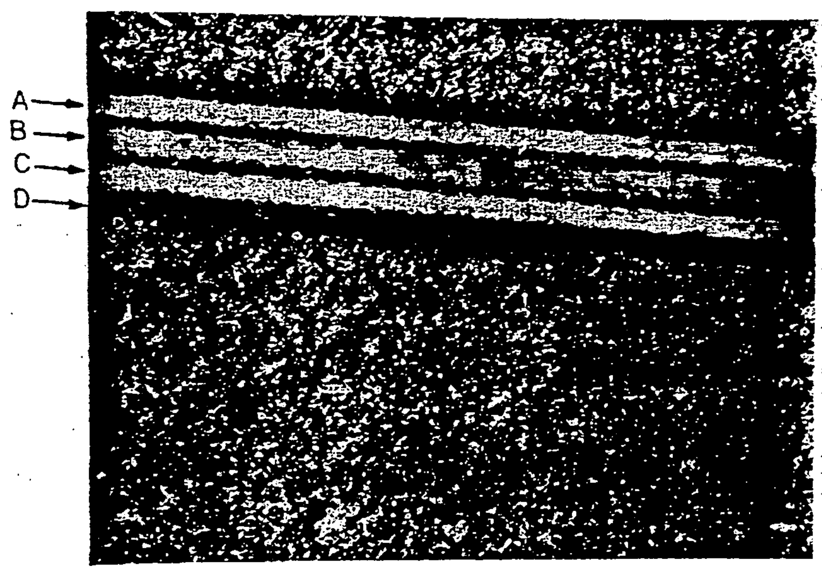



FIG.1A

FIG. 2



# LIQUID JET REMOVAL OF PLASMA SPRAYED AND SINTERED

The Government has rights in this invention pursuant to a contract awarded by the Department of the Air Force.

This application is a continuation of Ser. No. 07/441,666 filed Nov. 27, 1989 now abandoned.

## TECHNICAL FIELD

This invention relates to the removal of coating materials, and specifically to the removal of abradable, wear resistant, and thermal barrier coating materials which have been applied by either sintering powder or fibers, or by plasma spraying, utilizing liquid jet erosion.

## BACKGROUND ART

Various types coatings and sintered materials are used in numerous applications, such as in gas turbine engines to increase efficiency and/or protect components from heat and wear. Types of materials include thermal barrier coatings, abrasive coatings, abradable seals, and hard facing; hereafter referred to as coatings.

Since excessive blade/case clearances and disc/vane clearances within turbine engines allow the escape of gases which decreases engine efficiency, an abradable seal can be applied to minimize the clearances between the rotating and the stationary components. Thermal barrier coatings can be utilized to provide protection against high temperatures, while abrasive coatings can be used to prevent detrimental rub interactions and hard facing can be used to reduce wear.

Some coatings are applied by plasma or flame spraying; introducing particles (usually powders) into a hot gas stream or flame (respectively) which causes the particles to splat onto the substrate surface where they adhere and build up as a coating. Application of particles (i.e. AB-1) or short wires (i.e. Feltmetal TM) onto a substrate; by pre-sintering or partial sintering and then brazing, can be used to produce abradable coatings comprised of bonded particles, wires, or powders and void spaces; while bond coats can be produced by plasma spraying or vapor deposition. Bond coats are usually used in plasma spray and vapor deposition applications; a bond coat being a layer of metallic composition applied to the substrate before the coating is applied. U.S. Pat. Nos. 3,542,530, 3,676,085, 3,754,903, 3,879,831, 3,928,026, and 4,704,332, (incorporated herein by reference) describe various coatings, while U.S. Pat. Nos. 3,413,136, 4,055,705, and 4,321,311 (incorporated herein by reference) describe application techniques.

A common characteristic of these types of coatings is that the coating strength (cohesive strength) is relatively low; plasma sprayed or partially sintered particles are not well bonded to each other and there is usually porosity present. The strength of the coating is less than that of the substrate.

During engine maintenance, these coatings must frequently be removed; a process difficult to reliably preform and which frequently results in substrate damage. Various techniques have been employed for the removal of coatings: machining, chemical stripping, machining followed by chemical stripping (see for example U.S. Pat. Nos. 4,339,282, and 4,425,185; incorporated herein by reference), and grit blasting. For example, machining followed by chemical stripping requires that the component be held stationary while a machining tool removes the majority of the coating. A chemical solution, usually either a very strong acid or base, is then applied to the coating surface to disintegrate the remaining coating material. This technique requires extreme precision; without proper hardware alignment during machining damage to the substrate material occurs, while the chemical solution used tends to attack the substrate material. This process is also time consuming and labor intensive. Additionally, the chemical step, can produce hazardous waste. The individual processes of chemical stripping and machining also have the above described problems.

Another commonly used method, abrasive or grit blasting, also often results in damaged or destroyed components. This process consists of projecting abrasive particles in a compressed air stream against the coating. Since this technique requires immediate termination upon substrate exposure to prevent damage, it requires skilled operators.

Liquid jets above 10,000 psi, to the best of our knowledge, have not been utilized in the removal of coatings. Relatively low pressure liquid jets, 2,000 to 3,000 psi, have been applied in areas such as: cleaning applications, nuclear contamination removal, concrete scarifying, and barnacle and hull fouling removal, but not in an inorganic coating removal process.

Accordingly, an objective of this invention is to provide a convenient, cost effective, environmentally safe technique of removing coatings.

## DISCLOSURE OF INVENTION

The present invention involves the removal of coatings utilizing a liquid jet erosion process. The liquid jet, while striking the coating at an angle, traverses the region, removing the coating. Depending on the liquid pressure, the liquid stream erodes the abradable seal/thermal barrier with virtually no damage to the bond coat (if present), or can remove both the abradable seal/thermal barrier and bond coat simultaneously without substrate damage.

The invention process can be used to remove plasma sprayed and sintered coatings whose cohesive strength is significantly less than that of the substrate.

The foregoing and other features and advantages of the present invention will become more apparent from the following description and accompanying drawings.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a basic embodiment of this invention.

FIG. 1A is a cross-section of FIG. 1 which reveals the various layers of the coating.

FIG. 2 shows the results of utilizing a liquid jet removal process at varying pressures.

## BEST MODE FOR CARRYING OUT THE INVENTION

The removal of coatings using current techniques is a difficult, inexact process. It requires skilled technicians, a substantial amount of time, expensive equipment, and frequently, the component is destroyed.

The removal of the coating, bond coat, or both without damage to the substrate material can be achieved with a liquid jet erosion technique; making it a viable alternative to the prior art.

As previously mentioned, this invention uses a liquid jet erosion process to remove coatings. Critical parameters (see FIG. 1) include the nozzle distance from the

coating, and the liquid pressure. Depending on equipment and pressure constraints, the nozzle can be placed up to approximately 6 or even 12 inches from the coating surface, however, lesser distances are preferred, with ¼ to ¾ inch especially preferred.

The angle between the liquid jet and similarly the liquid contact, and the coating is a matter of preference. An angle of between 20° to 90° can be used, with an angle of between 30° and 90° preferred, and an angle of about 45° especially preferred (see FIG. 1). The angle, not a critical parameter, causes the liquid to remove the coating fragments from the region where the jet impacts the coating. The direction of rotation effects the fragment location post-removal. It is preferred to rotate the component such that it causes the liquid stream to move toward the smallest angle formed between the liquid stream and the component. Although this is merely a matter of preference, this rotation directions helps to remove the fragments from the interaction zone thereby ensuring that they to do not interfere with the process.

FIG. 1 is one embodiment of the invention. The liquid stream (5) contacts the coating (1) at the preferred angle, approximately 45°. Additionally, the component (10) rotates such that the liquid stream (5) moves toward the smallest angle between the liquid stream (5) and the component (10) (see arrows (1A)).

The liquid stream can consist of any liquid having a viscosity between 0.25 centipoise and 5.00 centipoise at 25° C. and 1 atm and which will not damage the bond coat or substrate material, including water based liquids. Higher viscosity liquids tend to present flow problems with respect to spraying the liquid at high pressures, while lower viscosity liquids can be difficult to pressurize, possibly increasing equipment costs. Water, viscosity approximately 0.95 centipoise at 25° C. and 1 atm, is preferred for reasons of cost and waste disposal. Additives, such as wetting agents, or various chemicals which will degrade the coating without damaging the component, may also be useful.

A water jet pressure sufficient to remove the top coat and/or the top coat and the bond coat is required. Since pressures greater than about 60,000 psi will damage most gas turbine substrate materials, lower pressures must be used. The optimum liquid pressure ranges from about 20,000 to about 60,000 psi, with about 25,000 to about 40,000 psi preferred. The factors which determine the exact pressure required include the type of top coat and if the coating is to be removed down to the bond coat or to the substrate. (see FIG. 1A; top coat (1) and bond coat (2)). Exact pressure limits are also related to nozzle geometry and spacing, and to the specific substrate involved. In practice, the skilled artisan can readily determine the pressure which causes substrate damage and/or the pressure which causes bond coat removal, and reduce this pressure to arrive at a suitable process pressure.

FIG. 2 shows the effects of varying pressures when using this invention. As the pressures decreased, from run (A) to (D), the amount of seal removed also decreases, to the point where the abradable seal/thermal barrier is removed with virtually no damage to the bond coat, (D).

This invention will be made clearer with reference to the following illustrative examples.

## EXAMPLE 1

The following procedure is used to remove a plasma sprayed hard face coating, top coat and bond coat, (consisting of 20 v/o of an 80 nickel, 20 chromium alloy, balance chromium carbide) from a substrate material.

1. The coated substrate material is arranged such that relative motion can be produced between it and the water jet nozzle.
2. The water jet nozzle is placed so that the exit end of the nozzle is about ¼ inch from the coating and the water stream contacts the coating at an angle of 45° (refer to FIG. 1).
3. The water pressure is 40,000 psi.
4. Relative motion is created between the water stream and the coating such that as the coating is removed the component advances to the next region to be removed.
5. The removal time is dependant upon the surface area of the coating. The time will range from 5 minutes to 10 minutes for typical gas turbine engine components.

## EXAMPLE 2

A sintered abradable coating (consisting of approximately 65 v/o nickel, 35 v/o chrome, balance aluminum) can be removed by following the specifications set forth in Example 1, while substituting a pressure of 35,000 psi for the 40,000 psi in step 4.

This process can be used for any coating which has strength less than that of the substrate, by adjusting the pressure such that it removes the top coat without bond coat damage, or the bond coat without substrate damage, allowing reuse of the bond coat and substrate or the substrate respectively.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention.

We claim:

1. A method for removing a top coat from a bond coating adhered to a substrate, utilizing a liquid jet, said liquid jet having means for directing the liquid jet, means for creating sufficient pressure to remove the coating, means to provide the relative motion between the coating and the liquid jet, and means for supplying the liquid, which comprises:
   a. creating sufficient pressure to remove the coating;
   b. providing relative motion between the coating and the liquid jet;
   c. supplying the liquid;
   d. causing the liquid to strike the top coat, wherein the liquid striking the top coat causes top coat erosion until the bond coat is exposed;

   whereby the bond coat and the substrate suffer essentially no damage and can be reused.

2. A method as in claim 1 wherein the top coat is selected from the group of plasma sprayed, flame sprayed, and sintered coatings.

3. A method as in claim 1 wherein the top coat is an abradable.

4. A method as in claim 1 wherein the top coat is a thermal barrier.

5. A method as in claim 1 wherein the top coat is an abrasive.

6. A method as in claim **1** wherein the coating is a hard facing.

7. A method as in claim **1** wherein the liquid pressure is from about 20,000 psi to about 60,000 psi.

8. A method as in claim **1** using a nozzle as the means for directing the liquid flow.

9. A method as in claim **1** wherein the liquid is selected from the group of liquids consisting of all liquid which does not degrade the bond coat, and has a viscosity between about 0.25 centipoise and about 5.00 centipoise at 25° C. and 1 atm.

10. A method as in claim **1** wherein the liquid is selected from the group consisting of water based liquids.

11. A method as in claim **1** wherein the liquid is essentially water.

12. A method as in claim **1** wherein the angle between the liquid stream and the top coat is between 20° and 70°; whereby the angle causes the liquid stream to clean away the coating fragments.

13. A method as in claim **1** further comprising the step of removing the bond coating, wherein the substrate material suffers essentially no damage.

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United States Patent [19]
Carr

[11] Patent Number: 4,731,125
[45] Date of Patent: Mar. 15, 1988

Patent Images

# [54] MEDIA BLAST PAINT REMOVAL SYSTEM

[76] Inventor: Lawrence S. Carr, 150 Silvarado Trail-#53, Napa, Calif. 94559

[21] Appl. No.: 767,696

[22] Filed: Aug. 21, 1985

Related U.S. Application Data

[63] Continuation of Ser. No. 601,805, Apr. 19, 1984, abandoned.

[51] Int. Cl.[4] ........ B08B 7/00
[52] U.S. Cl. ........ 134/17; 134/38; 51/298; 51/320
[58] Field of Search ........ 134/7, 38; 51/320, 298

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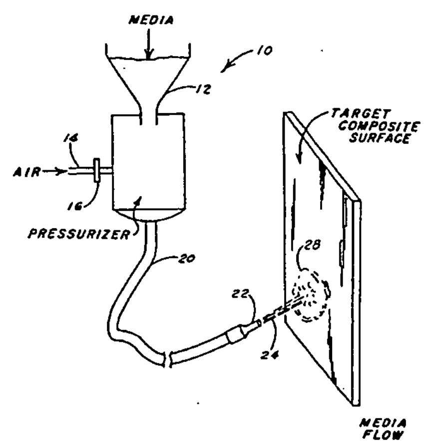
*Primary Examiner*—Helen M. S. Sneed
*Assistant Examiner*—Sharon T. Cohen
*Attorney, Agent, or Firm*—David C. Ripma

[57] ABSTRACT

A method is described for blast cleaning paint and other adhesive coatings from composite surfaces formed of a reinforced matrix material. A special soft media is used at a relatively low pressure to prevent damage to the soft composite material. The preferred method calls for the use of a media having a Mohs scale hardness number of 3.0 or less. The media is pressurized to approximately 40 p.s.i. and directed at the composite surface to be cleaned. A method of optimizing the cleaning action is also described.

13 Claims, 2 Drawing Figures



Patent Images

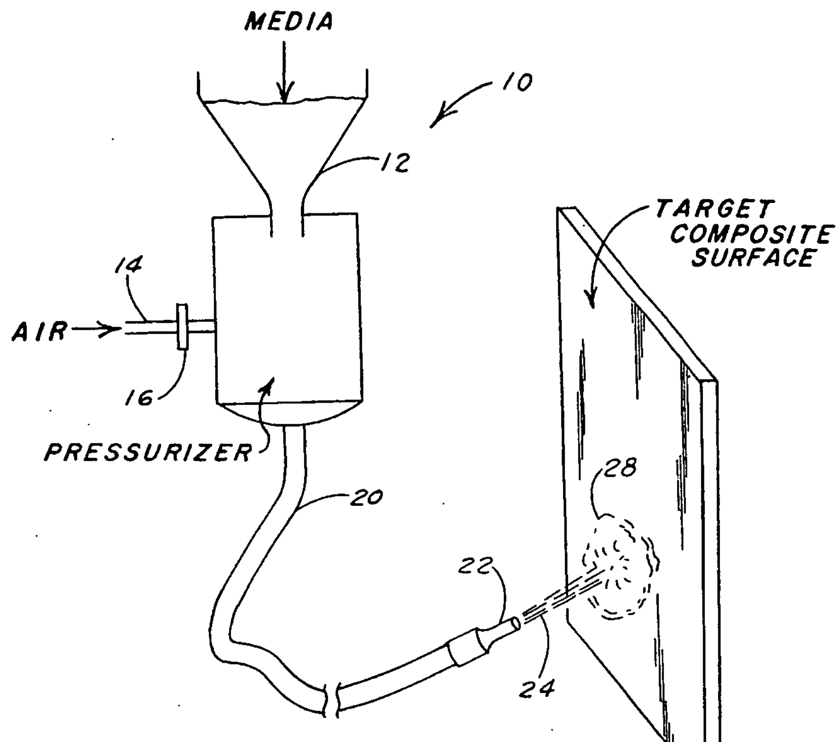



Fig. 1

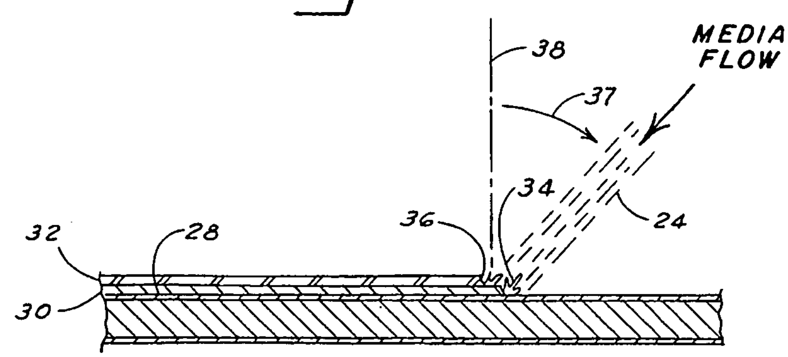



Fig. 2

## MEDIA BLAST PAINT REMOVAL SYSTEM

Patent Images

This is a continuation of Ser. No. 601,805, filed Apr. 19, 1984, now abandoned.

## BACKGROUND OF THE INVENTION

This invention relates generally to systems for removing adherent material, such as paint or other coverings, from surfaces, and more particularly to nonchemical surface cleaning systems employing mechanical blast.

For various types of structures and equipment, it is often necessary or desirable to remove the layer or layers of coatings which have been applied to surface areas. Numerous techniques exist for removing paint, sealants, lacquers and other adherent materials from virtually any type of surface. Surface cleaning or stripping methods range from mechanical abrasion to the use of strong chemicals, and involve varying degrees of time, effort and expense. For any given type of coating, the character and function of the substrate material from which a coating is to be removed ususally dictates the stripping method, at least in industrial settings. Hard, durable surfaces, such as heavy steel plating, can be cleaned or stripped by relatively fast abrasive methods, such as sand blasting. More delicate surfaces may require careful chemical removal to prevent damage or destruction of the substrate.

A certain class of materials, generally called composites, present special problems which have heretofore required the use of expensive and hazardous chemical treatments to remove surface coatings. Composites are usually made of a matrix material, such as plastic or epoxy, which often contains fibers such as glass strands, graphite, kevlar or the like for reinforcement. Layers of the material are laminated together or pressed onto a honeycomb base to form structural material. Composites are strong and light and are increasingly used in aircraft and other manufactured products where weight savings are important. Because composites usually have surfaces which are softer than metals, removal of paint or other coatings from composites must be done carefully to avoid excessive abrasion or chemical damage.

The greatest costs in both time and money associated with stripping and cleaning composites are probably encountered in the maintainance of modern aircraft, which incorporate large areas of exterior surface formed of composites. Airlines and the military spend large amounts chemically stripping paint and other coatings from aircraft, in preparation for repainting. The weight savings from stripping generally justifies the enormous expenditure in man-hours to strip an aircraft using chemicals and sanding.

Recent developments have indicated the effectiveness of a new stripping technique, similar to sand blasting, which is quicker and safer than chemical stripping. The system uses a granular media consisting of numerous particles of a plastic material accelerated to high speed and directed against the surface to be cleaned. The media particles can be of various sizes, depending on the application, and can be accelerated to produce a continuous media flow using conventional sand blasting equipment. This system has been shown to be highly effective in removing paint and other coatings from harder surfaces, such as metal, and also for deburring and other finishing processes and the like. It is far safer than chemical stripping, presents no hazardous waste disposal problems, and greatly reduces the man-hours and expense of surface cleaning. Blast cleaning with plastic media has been shown to be effective on the metal parts of aircraft, but was not previously considered suitable for stripping composites. Due to the relative softness of composites, as compared to metal, plastic media blast cleaning by prior art methods tended to score, abrade or otherwise damage composite surfaces to an unacceptable degree. Until the development of a blast cleaning method which solves such problems, aircraft and other surfaces made of composites have had to be cleaned and stripped by laborious and expensive prior art techniques.

It would be advantageous to have a less hazardous and more economical method of cleaning and stripping composite surfaces. The use of blast cleaning techniques for cleaning composites would be especially desirable since it would greatly reduce the cost and time for such cleaning. Any blast cleaning method used on composites must, however, not result in damage to the composite surface.

## SUMMARY OF THE INVENTION

Accordingly, the present invention provides a surface cleaning method for removing adherent material from composite surfaces formed of a reinforced matrix material. Steps in the method include the provision of a granular media substantially composed of particles of a material which has a Mohs scale hardness number lower than 3.5. The media is then accelerated using media propelling means to produce a substantially continuous media flow at a media outlet having a pressure of approximately 40 pounds per square inch or less at the media outlet. The media is directed at a target composite surface to be cleaned. Adherent material is removed from the target composite surface by the action of the media without damage to the composite surface.

In its preferred form, the method includes the use of a flexible tube and nozzle to direct the media at the target composite surface. The media flow is directed at a selected angle with respect to the composite surface to optimize the cleaning action. Steps are also set forth which minimize the possibility of damage to the underlying composite surface.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially schematic plan view of a system for performing the media blast surface cleaning method of the present invention.

FIG. 2 is a magnified cross-sectional view illustrating the removal of adherent layers from a composite substrate in accordance with the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is specifically directed to media blast cleaning of composite surfaces made up of a reinforced matrix material, and provides a system for removing paint and other coatings from such surfaces. As discussed above, the term composites, as used herein, refers to a class of increasingly important structural materials which possess the qualities of strength and lightness. "Reinforced matrix material" describes the general configuration of composites, in which reinforcing fibers are embedded in a matrix of polyester, polyurethane, vinyl ester, epoxy resin or another suitable matrix. The reinforcing fibers can be formed of graphite, glass, Kelvar (trademark) or other equivalent fibers. The making of structural panels or shapes from

composites generally includes bonding layers of the reinforced matrix sheets onto a honeycomb core, resulting in a tough, strong and lightweight material which resists impact and corrosion. If the honeycomb core is absent, the composite is fabricated as a solid laminate.

Despite their strength, composites have a relatively soft surface, compared to most metals, and are susceptible to wear and damage through abrasion. For this reason, prior art blast cleaning methods such as sand blasting cannot be used to remove adherent coatings from composites. The cleaning system of the present invention provides a method of cleaning and stripping composites which avoids damaging the relatively soft surface while permitting the use of efficient blast cleaning techniques.

A first step in the method is to provide a suitable blast cleaning media. It has been discovered that the most effective media for use on composites, which avoids surface damage when properly applied, is a plastic media with very specific properties. The media is composed of particles of a material having a Mohs scale hardness mumber of approximately 2.5 to 3.0. Particle hardness should not exceed a Mohs hardness of 3.5, as this has been found to damage composite surfaces. Plastic has been found to be the most suitable material for the media. Urea formaldehyde or another thermoset plastic can readily be formed into granular particles for this purpose. A Mohs hardness of 3.0 is substantially softer than other blast media, such as sand, which has a Molus hardness of 7. It is the relative softness of the media, in combination with the method desribed below, which prevents damage to composite surfaces. A suitable commercially available media which can be used with the present invention is Polyextra (trademark) Blast Cleaning Media, manufactured by the U.S. Plastic and Chemical Corporation.

Blast media such as Polyextra are generally classified as to particle size by U.S. standard sieve sizes. While it is not believed to be critical, media with a sieve size of 20–30 is known to be suitable for use with the present invention. It is anticipated that media having sieve sizes ranging from 12–16 to 60–80 can be used, with the selection of the size being based on the particular application.

The next step in the method is to accelerate the media to a flow which is effective for blast cleaning. Acceleration can be accomplished by a suitable media propelling means, such as a pneumatic sand blaster, or similar device. Preferably, the media propelling means will have a movable media outlet such as a nozzle, which allows the media flow to be directed over a target composite surface area to be cleaned. The media propelling means should produce an output pressure for the media flow of approximately 40 pounds per square inch (p.s.i.). That is a lower pressure than is used in most sand blasting operations. Conventional sand blasters can often be modified to output media at 40 p.s.i. by a simple adjustment, or, in some cases, by the addition of a pressure regulator to the equipment. Although the pressure of the media flow need not be exactly 40 p.s.i. to practice the present invention, it is important that pressures substantially higher than 40 p.s.i. not be used since higher pressures tend to damage composites. A suggested range for the pressure of the media flow at the output nozzle is between 35 and 45 p.s.i.

FIG. 1 illustrates a typical configuration for practicing the present invention. Pressure blast cleaning equipment is illustrated generally at 10. An example of such equipment suitable for use with the present invention is the pressure blast cleaning equipment manufactured by Clemco Industries. Such equipment includes a reservoir of media 12 to be accelerated. Pneumatic pressure blast cleaners also include an inlet line 14 from a source of pressurized air or other gas (not shown). A pressure regulator 16 may also be provided to reduce the inlet pressure supplied through line 14. The outlet from media propeller 10 includes a long flexible tube or hose 20 through which the pressurized media flows. At the end of hose 20 is a nozzle 22 which serves as a media outlet and as a means for directing the media flow 24 emerging from the nozzle. The media flow 24 will be a mixture of pressurized air or other pressurizing gas and the media particles, which will emerge in high volume and at relatively high speed. For the purposes of practicing the present invention, media flow 24 will be substantially continuous and have a pressure at nozzle 22 of approximately 40 p.s.i.

The diameter of nozzle 22 determines the diameter of media flow 24. A larger nozzle size requires a greater volume of pressurized air at inlet line 14 and produces a correspondingly larger volume of media flow at nozzle 22. Nozzle sizes of ¼ inch and ½ inch have been proved effective with the present invention, although larger sizes can be used if pressure blast equipment of sufficient capacity is available. Regardless of the nozzle size, it is anticipated that the media flow will be confined by nozzle 22 to a diameter which is substantially smaller than the size of the target composite surface 28 to be cleaned. As such, the media flow will be directed over the target composite surface in the manner described below in order to remove adherent material from surface 28.

Directing media flow 24 at the target composite surface constitutes the next step in the method of the present invention. It is anticipated that in most applications of the present invention the surface to be cleaned will be stationary and the nozzle will be moved to clean the surface. For example, in cleaning composite surfaces on an aircraft fuselage or the like, a person holding the nozzle will direct the media flow over the target surface in a varying manner until the surface is cleaned.

In order to remove paint and other adherent material efficiently from composite surfaces, it is preferable that the path of the media flow against the target surface be optimized. An optimal path of media flow will be one in which the angle and direction of the media flow produces highly efficient removal of adherent material from the surface without damage to the composite surface. This is generally done by angling the media flow away from a perpendicular direction with respect to the target surface so that the leading edge of the coating being removed is exposed to the force of the media flow. FIG. 2 illustrates an optimal path of media flow with respect to a target composite surface 28. Assuming there are two adherent layers of paint 30 and 32 to be removed from surface 28, an optimal path of media flow will be approximately as shown in FIG. 2. The media flow will be directed at the leading edge 34 of layer 30 and also against leading edge 36 of layer 32. The angle 37 of the media flow with respect to perpendicular 38 is increased to increase the rate of removal of layers 30 and 32. It has been found that an increase in angle 37 results in more media particles being available to dislodge the adherent layers at the leading edge. For this reason, it is preferred that angle 37 be increased until the observed effectiveness of the removal action is maxi-

mized, and that angle then becomes the optimal path of media flow.

Another preferred step in the cleaning process is the efficient redirection of the media flow over the target composite surface until the entire surface is cleaned. It has been found that this is best accomplished by directing the media flow primarily at areas of adherent material remaining to be removed, and then redirecting the media flow to other unremoved areas whenever removal in the first area is substantially accomplished. In this way, exposure of cleaned, and therefore unprotected, composite surface to the full force of the media blast is minimized. During the entire cleaning process, an optimal path or angle of media flow is preferably maintained. Only at the start of the cleaning process or at other times when obstructions prohibit selection of an angle for the media flow will it be best to keep the media flow perpendicular to the target surface. At other times, the maintenance of an optimal path in response to the observed effectiveness of action of the media flow will produce the most efficient and effective surface cleaning action by the media flow.

The above-described process for the removal of adherent material from composite surfaces has proven to be superior to prior art surface cleaning techniques. Media blast eliminates entirely the need to use hazardous chemicals for surface cleaning. Not only is there a substantial savings of both time and labor, but the health, safety, pollution and disposal problems associated with chemical paint stripping are entirely eliminated. Other advantages of composite surface cleaning by the present invention include the ability to selectively remove outer layers of material while having underlying layers intact. This can be done by carefully directing the media flow at an area only until the desired layers are removed, leaving remaining layers intact. While such selective removal cannot be performed in some circumstances, such as where an underlying layer is too soft to remain intact, it is virtually impossible to perform selective removal with chemicals.

The composite surface cleaning system can be modified to meet the needs of particular situations. For example, the blast pressure media particle size and angle of media flow can all be modified within the limits described above in order to facilitate efficient cleaning without damage to the composite surface. Small or angled nozzles can be employed in confined areas or to reach otherwise inaccessible parts of a composite surface. Other modifications within the scope of this invention include the use of other types of media propelling means or of other means to direct the media flow.

The invention provides a less hazardous and more economical method of cleaning and stripping paint and other adherent materials from composite surfaces. The method allows for the use of efficient blast cleaning techniques without damage to relatively fragile composite surfaces.

What is claimed is:

1. A method of removing paint from the surface of composite structural material which is formed of bonded layers of a fiber reinforced matrix, in which the matrix is a type of material selected from the group consisting of polyester, polyurethane and epoxy and the reinforcing fibers are strands selected from the group consisting of glass, graphite and Kevlar, the method comprising the steps of: providing a granular plastic media consisting of particles of plastic material having a Mohs scale hardness number in the range of 2.5 to 3.5, accelerating said media using media propelling means to produce a substantially continuous media flow for blast cleaning paint from a target composite surface without damaging the underlying composite surface, including producing said substantially continuous media flow at a pressure of 40 pounds per square inch or less at a media outlet, and directing said media flow at the target composite surface whereby paint is removed by the action of said media flow.

2. A method as in claim 1 including providing a nozzle at said media outlet which confines said media flow to a portion of said target composite surface, and then directing said media flow in a varying manner over said target composite surface until the paint to be cleaned from said target composite surface is removed.

3. A method as in claim 2 in which said step of accelerating said media using media propelling means further includes directing the resultant media flow along a flexible tube toward said nozzle such that said nozzle is freely movable with respect to said target composite surface.

4. A method as in claim 3 including the step of maintaining the target composite surface stationary while moving said nozzle to direct said media flow in a varying manner over said target composite surface.

5. A method as in claim 1 which said step of directing said media flow at a target composite surface includes selecting an optimal path of media flow against said target composite surface by selecting the angle at which said media flow strikes said target composite surface to optimize the removal of paint.

6. A method as in claim 5 including the steps of providing a nozzle at said media outlet which confines said media flow to a portion of said target composite surface, and directing said media flow over said target composite surface by moving said nozzle with respect to said target composite surface, including maintaining a substantially optimal path of media flow while redirecting said media flow over said target composite surface.

7. A method as in claim 6 in which said step of directing said media flow over said target composite surface while maintaining a substantially optimal path of media flow further includes providing a pattern of direction for said media flow which includes directing said media flow primarily at areas of paint remaining to be removed and redirecting said media flow when removal is substantially accomplished to other areas of paint remaining to be removed in a substantially continuous cycle whereby exposure of cleaned areas of said target composite surface to said media flow is minimized.

8. A method as in claim 6 in which said step of accelerating said media using media propelling means further includes directing the resultant media flow along a flexible tube toward said nozzle such that said nozzle is freely movable with respect to said target composite surface.

9. A method as in claim 8 further including varying the direction of said media flow with respect to said target composite surface in a substantially continuous manner until the paint to be cleaned are removed from the entire target composite surface.

10. A method as in claim 8 including the step of maintaining the target composite surface stationary while moving said nozzle to direct said media flow in a varying manner over said target composite surface.

11. A method as in claim 5 in which the selection of an optimal path of media flow includes increasing the angle away from a perpendicular direction at which

said media flow strikes said target composite surface until the effectiveness of the media flow in removing paint is maximized.

12. A method as in claim 1 in which said step of accelerating said media using media propelling means includes pressurizing said media means of pneumatic pressure.

13. A method as in claim 1 in which said step of providing a granular plastic media includes providing a media formed of granular particles of urea formaldehyde.

* * * * *

# United States Patent [19]

**Shiembob**

[11] **4,433,845**

[45] **Feb. 28, 1984**


[54] **INSULATED HONEYCOMB SEAL**


[75] Inventor: **Lawrence T. Shiembob**, Rocky Hill, Conn.

[73] Assignee: **United Technologies Corporation**, Hartford, Conn.



[21] Appl. No.: **306,838**

[22] Filed: **Sep. 29, 1981**

[51] Int. Cl.³ .............................................. **F16J 15/40**

[52] U.S. Cl. .......................................... **277/1**; 277/53; 277/227; 415/174; 427/423

[58] **Field of Search** ...................... 277/53, 1; 415/174, 415/177; 427/423, 34



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*Primary Examiner*—Robert I. Smith

*Attorney, Agent, or Firm*—Charles A. Warren


[57] **ABSTRACT**

The application discloses the manufacture of a seal for a row of turbine blades in which the seal is a honeycomb seal and a layer of insulation is positioned in the cells of the honeycomb by flame spraying. A process for accomplishing the deposition of the insulation is also described.


**6 Claims, 3 Drawing Figures**

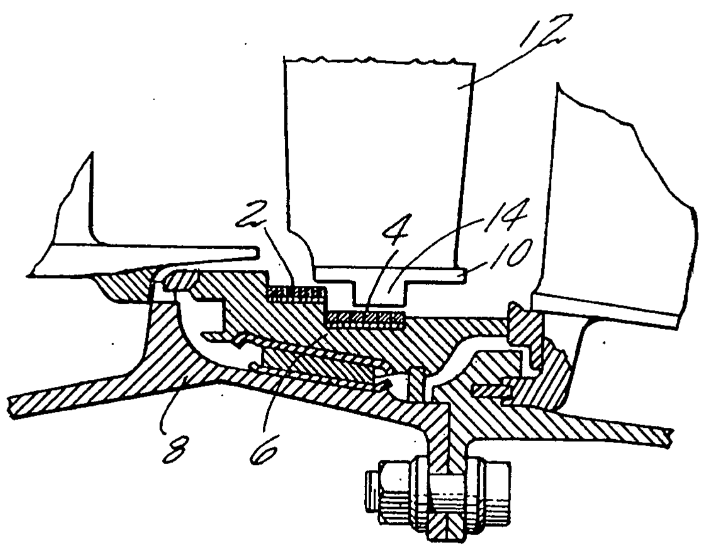


Fig. 1

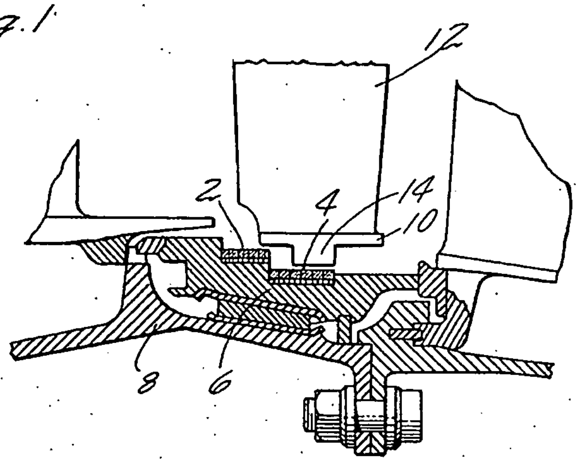



Fig. 3

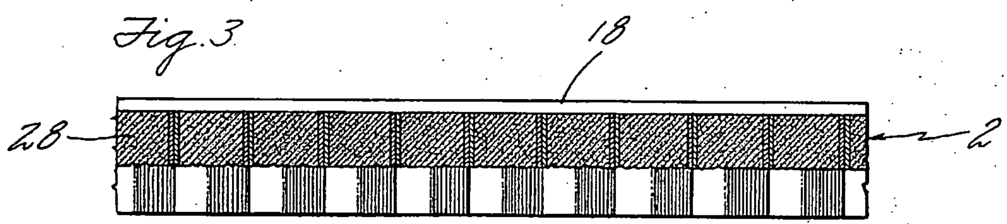
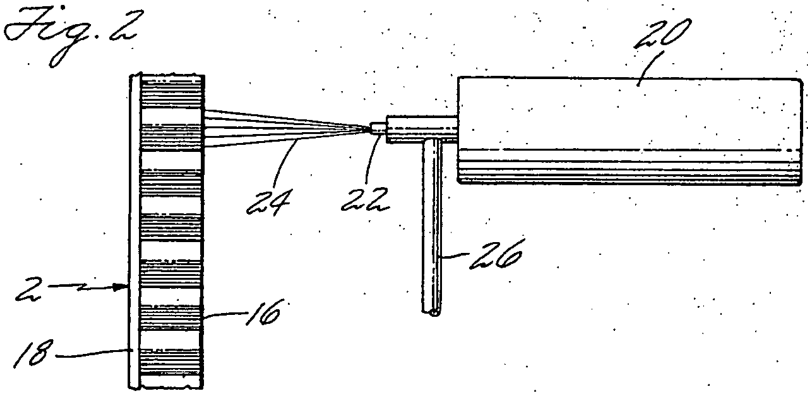



Fig. 2



# INSULATED HONEYCOMB SEAL

## DESCRIPTION

1. Technical Field

This invention relates to honeycomb type of seals for gas turbine engines in which the seal that surrounds a row of blades in the engine is at least partially filled with an insulating material to reduce the thermal gradients in the turbine case and thus minimize contact between the blades and the seal.

2. Background Art

To reduce the gas path seal clearances during engine transients attempts have been made to insulate the seals and their supports to reduce the thermal response of the parts. Where the seal is a honeycombed material the honeycomb has been filled with a paste form of insulation which is then brazed or sintered to set and bond the material. This procedure is difficult to monitor to assure a uniform filling of the honeycomb with the result that there is uneven insulation throughout the honeycomb. When it is desirably only to partially fill the honeycomb in certain installations, a uniform filling to the extent desired is even more difficult.

## DISCLOSURE OF INVENTION

One feature of the invention is the application of the coating of the insulating material as a powder by flame spraying this powder to the desired depth of thickness in the cells of the seal. Another feature is the use of a NiCrAl/bentonite powder as the insulating material. Another feature is the use of this powder in flame spraying applications which provide the desired bond and insulating properties as well as the desired hardness of the coating.

According to the invention a suitable insulating poweder is deposited to the desired depth or thickness in the honeycomb seal by flame spraying the powder into the cell structure of the honeycomb. The desired insulating powder is a NiCrAl/bentonite powder in which the particles consist of a bentonite core coated with a mixture of NiCrAl. The principal feature of the invention is the application of an insulating powder to the cells of a honeycomb by a flame spraying procedure by which to assure a uniform application of the insulating coating to the desired depth in the honeycomb and to produce an insulating structure that has the desired characteristics without further treatment beyond the flame spraying.

The foregoing and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of the preferred embodiment thereof as shown in the accompanying drawing.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a fragmentary sectional view through a turbine showing the location of the honeycomb seal.

FIG. 2 is an enlarged sectional view showing the coating applied to the seal.

FIG. 3 is an enlarged sectional view of the seal.

## BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1 the honeycomb seals 2 and 4 are shown as supported by a seal ring 6 positioned within the turbine casing 8. The seal 2 has a smaller diameter than the seal 4 and engages the shrouds 10 of the turbine blade 12 adjacent to the leading edges of these shrouds. The seal 4 has a larger diameter and surrounds and is closely adjacent to a central rib 14 on the shrouds. Desirably the seals have a minimum of clearance with the shrouds to reduce the leakage of gas past the seals and the honeycomb material is selected as a seal since it will wear away readily in the event of contact with the blade shrouds during engine transients without any detrimental effect on the turbine.

It is desirable to reduce the heat transfer from the gas going through the turbine to the seals thereby reducing the rate of change in diameter of the seals during engine transients. As above stated this has been done by manually packing an insulating material in paste form into the honeycomb seals. Such a procedure is time consuming and does not result in a uniform distribution of the paste in the openings of the seal particularly, if the seal openings are to be only partially filled. To provide a better and more dependable insulation it has been found that suitable insulating powders may be flame sprayed into the seal and will produce the desired uniform insulating effect with the desired depth of insulation in the honeycomb spaces or cells. Further the flame spraying produces a better adherence of the insulating material with more uniform insulating properties. The material is also cured to the desired hardness by the flame spraying thereby avoiding any further heat treatment of the seal with the insulation therein.

Referring now to FIG. 2 the seal 2 being honeycomb has openings or spaces 16 therein extending radially and the outer ends of these spaces or cells are closed by the surrounding seal ring 18. To accomplish the desired insulation of this seal a suitable insulating powder having desired insulating characteristics is flame sprayed into the spaces or cells to the desired length. In the particular seal shown the cell dimension is one-sixteenth inch and the height of the honeycomb is 0.100 inch. The powder is flame sprayed into the cells to provide insulation 28 to a depth of $0.050\pm0.020$ inch within the cell. It will be understood that these dimensions are given by way of example and the cell size or depth of insulation are not critical to the invention.

The preferred powder consists of particles of bentonite which is normally 70% $SiO_2$ and 20% $Al_2O_3$ by weight and these particles are coated with a mixture of NiCrAl to produce a composition in the powder of chromium 1.5 to 6.5%, aluminum 1.0 to 6.0%, bentonite 18 to 24%, nickel remainder. It will be understood that any insulating powder capable of being applied by flame spraying may be used instead of this particular powder although it is known that this particular powder produces a very satisfactory insulating coating. The seals are preferably cleaned before flame spraying to assure a cool bond with the insulating material and the powder is then sprayed in with conventional spray equipment capable of producing the desired coating density.

The insulating powder may be sprayed on, for example, by a flame sprayer 20 having a nozzle 22 discharging a flame 24 against the seal. The powder is applied by a tube 26 delivered through the nozzle to enter the flame and be deposited on the seal. The nozzle is moved axially relative to the seal and parallel to the surface thereof while the part is rotating for depositing the material. The nozzle is also desirably reciprocated axially past the seal during the circumferential movement to assure a uniform deposit in all of the cells of the seal. The normal flame spray deposition covers a relatively

small area and would not normally be wide enough to fill the cells across the entire width of the seal without this axial movement. The insulation **28** is shown as applied only from the bottom of the cell up to the desired depth. It has been found that by flame spraying in the manner described substantially none of the insulating powder adheres to the side walls of the seal between the insulation and the open end of the seal.

One critical time in turbine operation is during deceleration when the cooler gas passing over the seals and the support structure causes these structures to shrink more rapidly than the rotor with the possibility of seal and shroud contact. This particular arrangement of insulation reduces the rate of shrinking of the seal to avoid this seal and shroud contact. Since engine clearances are set for this condition the use of this insulation enables a reduction in the engine design clearances at this point and the result is a higher performance engine because of reduced leakage past the seal.

Although the invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that other various changes and omissions in the form and detail thereof may be made therein without departing from the spirit and the scope of the invention.

I claim:

**1.** In the manufacture of a seal for a row of turbine blades the steps of:

providing a honeycomb seal with the cells therein substantially radial;

closing the outer ends of the cells by a surrounding ring; and

flame spraying an insulating material into the cells to fill at least partially the cells radially inward from the outer ends, the insulating material being clay particles with an alloy coating and

curing this material to the desired hardness by the heat of the flame spraying.

**2.** The process of claim **1** including the step of using as the insulating material to be flame sprayed a powder in which the particles are NiCrAl/bentonite.

**3.** The process of claim **1** in which the particles are in the form of a core or bentonite with a NiCrAl coating thereon.

**4.** A turbine seal for a row of turbine blades including:

a honeycomb seal ring in which the cells of the honeycomb extend radially;

a surrounding ring closing the outer ends of the cells; and

an insulating material positioned in said cells by flame spraying an insulating powder into said cells in which the insulating material is a clay base combined with a metallic alloy, that is heat cured to the desired hardness in the flame spraying operation.

**5.** A turbine seal as in claim **4** in which the material that is flame sprayed is in the form of particles having a bentonite core and NiCrAl coating.

**6.** A turbine seal as in claim **4** in which the insulating material is NiCrAl/bentonite.

* * * * *

# United States Patent [19]

**Ryan**

[11] **4,409,054**

[45] **Oct. 11, 1983**

[54] **METHOD FOR APPLYING ABRADABLE MATERIAL TO A HONEYCOMB STRUCTURE AND THE PRODUCT THEREOF**


[75] Inventor: Edward J. Ryan, Wallingford, Conn.

[73] Assignee: United Technologies Corporation, Hartford, Conn.



[21] Appl. No.: 225,074

[22] Filed: Jan. 14, 1981

[51] Int. Cl.³ ....................... B29C 19/00; B32B 31/00; B32B 3/12; B23K 35/24

[52] U.S. Cl. .................................... 156/293; 156/298; 228/243; 228/256; 415/174; 29/DIG. 4; 428/117

[58] Field of Search ............... 228/182, 248, 243, 245, 228/254, 255; 415/174; 277/81 R, 95; 29/432, DIG. 31, DIG. 4; 156/154, 293, 298, 303.1, 82, 89; 165/69, 1; 428/117, 446, 430, 553, 443, 555; 419/1, 4, 20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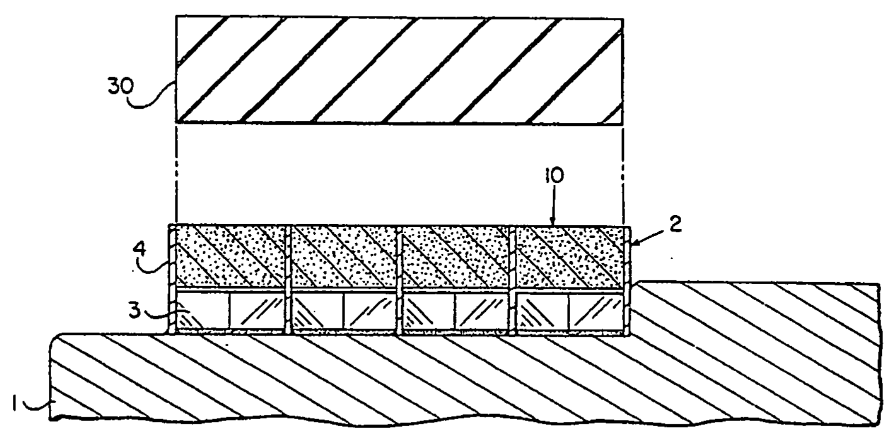
*Primary Examiner*—Edward C. Kimlin
*Assistant Examiner*—Louis Falasco
*Attorney, Agent, or Firm*—Charles E. Sohl

[57] **ABSTRACT**


Honeycomb structures, such as those used in turbine engine abradable seals, are provided with a uniform density filling of a suitable abradable material. The abradable material is prepared as a tape preform using an organic binder. The preform is forced into the honeycomb using a rubber tool.


**1 Claim, 4 Drawing Figures**



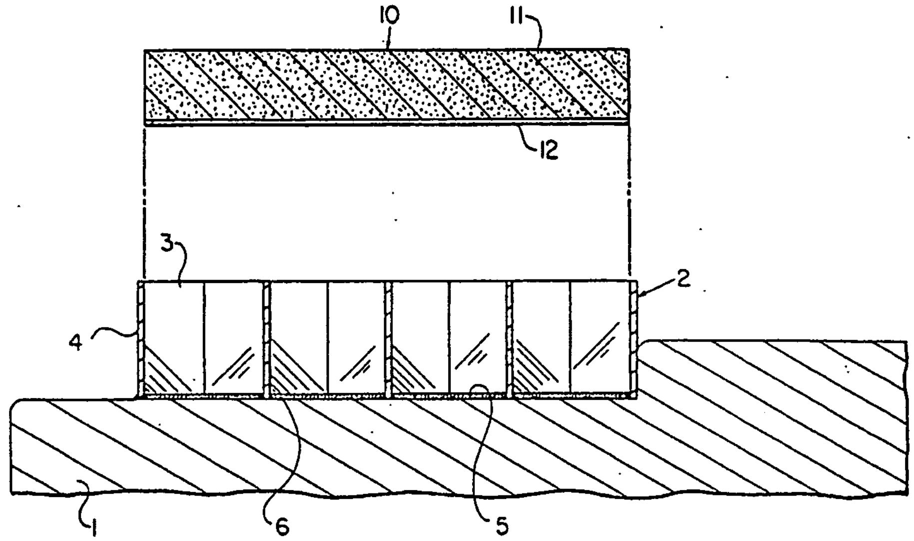



FIG. 1

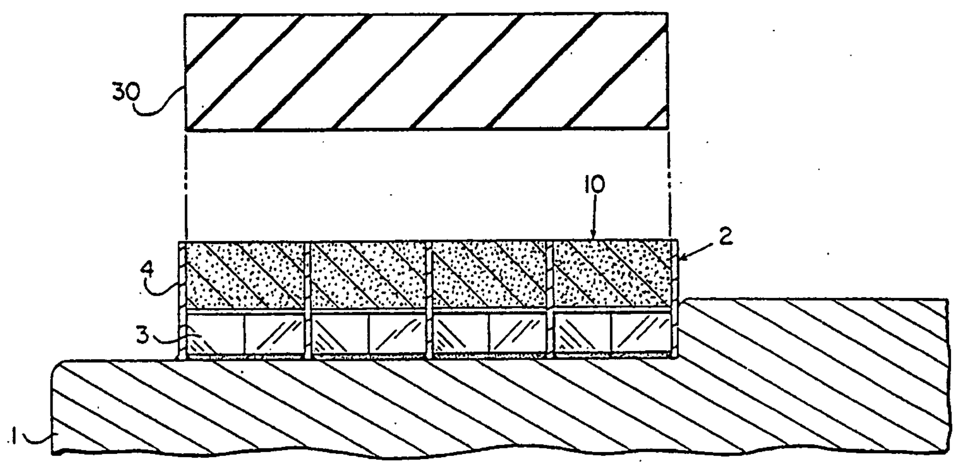



FIG. 2

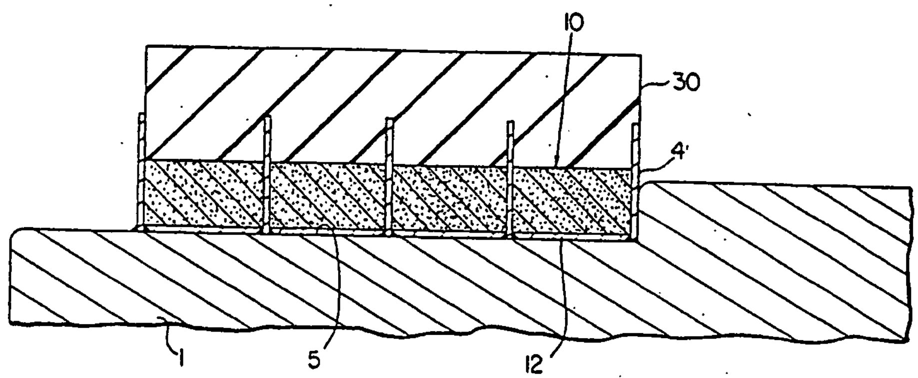



FIG. 3

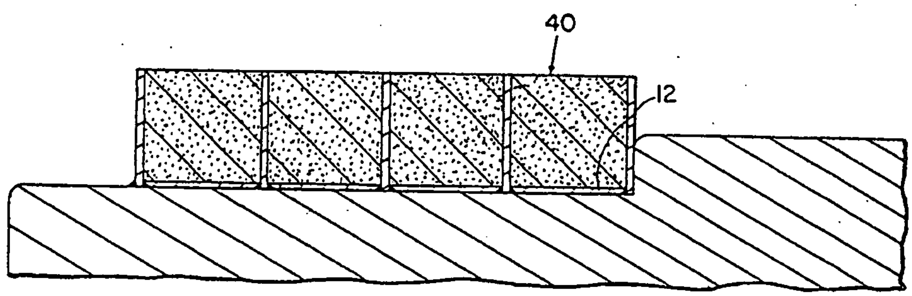



FIG. 4

# METHOD FOR APPLYING ABRADABLE MATERIAL TO A HONEYCOMB STRUCTURE AND THE PRODUCT THEREOF

## TECHNICAL FIELD

This invention relates to a method for applying abradable material to the cells of a honeycomb structure and to the resulting filled honeycomb.

## BACKGROUND ART

It is known in the art to use an abradable material in a rotating machinery application to form a good seal between a moving and a stationary part. This result is obtained by permitting one part to cut a channel or groove into the abradable material. In a gas turbine engine the abradable material is usually placed on the stationary case and the rotating blades cut a groove into the abradable material. In this fashion the changes that may result from thermal growth and blade creep are accommodated. Abradable materials are often located and restrained by being placed in a supporting honeycomb structure.

A typical patent which discloses an abradable material is U.S. Pat. No. 3,879,831. The contents of this patent are incorporated by reference. This patent discloses an abradable material having a total composition of 60-80% Nickel, 2-12% chromium, 1-10% cobalt, 4-20% aluminum and 3-15% inert material such as diatomaceous earth, boron nitride, silica glass, mica, vermiculite asbestos, molybdenum disulfide, graphite, cobalt oxide, cerium oxide and zinc oxide. Up to 3% of a metal selected from the group consisting of yttrium, hafnium and lanthanum may also be added. Table 1 in the patent lists the abradable material components and the preferred particle sizes. Coated diatomaceous earth which is referred to is a product of the Sherrit-Gordon Corporation consisting of diatomaceous earth which has been coated with nickel or an alloy of nickel and chromium.

Similar teachings are found in U.S. Pat. No. 3,817,719 which is also incorporated herein by reference. Such known abradable materials have been applied to honeycomb structures by mixing the dry constituents with a liquid binder such as cellulose nitrate to form a paste and then packing the material into the honeycomb cells. With this method of applying the material to the honeycomb structure various difficulties have been encountered. The uniformity of application is quite variable; consequently, when a complete filling of the cells is desired, it may not be consistently achieved. The results depend to a large extent on the skill of the operator. Further, for those applications which require a partial fill of the honeycomb cells, so that only the bottom half of the cells contain the abradable material, this technique is not capable of producing the desired results.

## DISCLOSURE OF INVENTION

An object of this invention is to provide a pliable tape preform consisting of at least one region which contains an substantial amount of a braze material and a second region which is composed primarily of an abradable material. Another object of this invention is to disclose application techniques for using this preform to produce honeycomb structure which is either partially or completely filled with abradable material. Yet another object of this invention is to provide a honeycomb structure which is only partially filled with abradable materials. Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.



## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 shows a cross section of an abradable tape and a honeycomb structure prior to insertion of the abradable tape.

FIG. 2 shows a honeycomb structure after the abradable tape has been partially inserted.

FIG. 3 shows a honeycomb structure after complete insertion of an abradable tape forming a partially filled honeycomb structure.

FIG. 4 shows a honeycomb structure after complete insertion of an abradable tape forming a completely filled honeycomb structure.

## BEST MODE FOR CARRYING OUT THE INVENTION

The present invention relates to honeycomb structures which are at least partially filled with an abradable tape and to methods for producing such structures. The honeycomb structure consists of a multiplicity of hexagonal cells which are separated from each other by thin metal cell walls. Each cell is open at one end while the other end abuts a substrate. "Partially filled honeycomb cells", denote a structure having an abradable composition which extends from the substrate upwards in the cell in a uniform fashion but which does not extend to the top of the cell.

Abradable materials are a class of materials characterized by a high degree of porosity, oxidation resistance, low thermal conductivity and the ability to be cleanly abraded away in a localized area. Typical of such materials are those described in U.S. Pat. Nos. 3,879,831 and 3,817,719. The exact abradable material used is a matter of choice and depends on the particular applications.

Braze materials are a class of relatively low melting point materials often based on nickel or gold with additions of various melting point depressants. The particular braze material used will depend in part on the abradable material and the substrate composition.

The present invention employs a pliable composite tape preform consisting of a thin layer which contains a substantial quantity of a metallic braze material and a thinner layer comprised of the abradable material. The composition tape may be produced using the teachings of U.S. Pat. No. 3,293,072 which is incorporated herein by reference. This patent shows how a tape preform may be produced using a removable carrier film as a substrate and employing an organic polymer such as polyvinyl alcohol or polymethacrylates along with a smaller amount of a volatile plasticizer such as sucrose-acetate isobutyrate, dibutylphthalate or diethyl-oxalate, for use with the polymethacrylate binders, and glycerine for use with the polyvinyl alcohol binders. The powder material is formed into a slurry with the binder, plasticizer and acetone, as solvent, applied as a thin layer to the removable substrate and then heated to remove the solvent.

The present invention will be better understood through reference to the illustrative figures which accompany the specification. FIG. 1 is a cross-sectional view of the honeycomb structure and the tape configured abradable material prior to insertion of the abrad-

able material into the honeycomb. In the figure, the honeycomb structure is supported on a substrate 1 and is typically attached thereto by brazing. The honeycomb structure 2 consists of a continuation of hexagonal cells 3 which are defined by thin metal walls 4. The cells 3 are opened at the top and closed at the bottom by the substrate surface 5. The honeycomb structure 2 is joined to the substrate 1 by brazing at the junction between the cell walls 4 and the substrate surface 5. This braze junction appears in FIG. 1 but is deleted in subsequent figures for clarity. Above this substrate cell structure is shown a tape 10 which consists of the abradable portion 11 and the braze portion 12. As previously indicated, this tape is somewhat flexible and pliable as a consequence of the retained binder and plasticizer which will be removed subsequent to installation of the tape-abradable in the honeycomb structure.

FIG. 2 shows the same components as shown in FIG. 1 after the tape-abradable material has been partially inserted into the honeycomb structure. Also shown in FIG. 2 is a rubber strip 30 whose purpose is to insert and locate the composite abradable tape into the honeycomb structure. In FIG. 2 the composite tape 10 has been forced into the honeycomb cell structure 2 and the cell walls 4 of the honeycomb structure have cut the abradable composite tape cutting the tape into hexagonal pieces which closely conform to the honeycomb cells. Insertion of the composite abradable tape into the honeycomb cell structure can be accomplished by using a flat plate or roller to force the material down into the individual honeycomb cells. The insertion tool used, whether a plate or roller should preferably have some resilience so as to ensure complete insertion of the tape into the cell structure and to minimize the possibility of damaging the individual cell walls 4 by the application of excessive force. The rubber strip 30 is used to completely insert the composite tape abradable material into the honeycomb cells and to ensure that the abradable material is firmly seated at the bottom of the individual cell segments. This is shown in FIG. 3. During the insertion process the rubber strip 30 is itself cut by the cell walls 4 as was the abradable tape during its initial insertion. An isostatic force is applied to the abradable material by the rubber strip 30 which ensures that the abradable material is firmly seated at the bottom of the cell structure so that the braze layer 12 at the bottom of the abradable tape 10 makes good contact with the surface 5 of the substrate 1. This good contact is necessary to ensure that a good braze joint is formed upon subsequent heating. Following the complete insertion of the composite abradable tape into the cell structure using the rubber strip, the strip 30 is then removed leaving the composite abradable material in the cell structure. If the rubber strip is not completely removed it will be decomposed during the heating which is performed to remove the binder and plasticizer and the heating which is necessary to form the braze joint between the braze layer 12 and the substrate surface 5.

Certain properties are necessary if the rubber material which is used to form the strip 30 is to properly perform its task of forcing the composite abradable tape down into the honeycomb cells. The material must be pliable and compressible to a limited extent so that it can conform to any irregularities of composite tape thickness which may occur. Most importantly the rubber material must have a relatively low shear strength so that the honeycomb cell walls will easily and accurately cut their way into the rubber material. Adequate results have been obtained with a blend of approximately 50% glass micro-spheres and room temperature vulcanizing rubber (RTV) appropriately cured.

The following description of a specific process is intended to illustrate the invention but is not intended to limit the invention. It was desired to fill a honeycomb structure having the cells of ⅛ inch in size which were about ⅛ inch deep. The intended filler material was that material described in U.S. Pat. No. 3,879,831. A composition consisting of 30% by weight of the nickel chromium alloy (80% nickel-20% chromium) having a particle size of minus 230 mesh and 15% by weight of a cobalt-aluminum-yttrium alloy (30% cobalt, 69% aluminum, 1% yttrium) having a particle size of minus 325 mesh and 55% by weight of nickel coated diatomaceous earth (85% nickel, 15% diatomaceous earth) was mixed and throughly blended in the dry state. This mixture represents the components which were to form the abradable material. A braze composition known as AMS 4778 (92% nickel, 3% boron, 4.5% silicon) was provided for use in bonding the abradable material to the substrate. The braze material was provided as a powder of minus 325 mesh size. Two tapes were formed according to the process described in U.S. Pat. No. 3,293,072. One tape was comprised of 75% by weight of the previously described abradable mixture and 25% by weight of the braze material. The thickness of this tape was less than 10 mils. The second tape was comprised completely of the abradable material and had a thickness of 40 mils. These two tapes were pressed together while they were still in a sticky condition and adhered to each other as a consequence of the liquid binder which was present in each tape. This abradable tape was placed over a honeycomb structure with the braze rich layer facing the honeycomb structure and was pressed into the honeycomb structure using a roller. A strip of the previously described rubber material was then placed over the partially filled honeycomb and the roller was then used to force this rubber material into the cells and consequently force the abradable tape material down to the bottom of the honeycomb cells. The rubber strip was removed and the partially filled honeycomb material was then baked at a temperature of about 1200° F. for a period of about 30 minutes to decompose and evaporate or sublimate the binder and plasticizer and was then heated at a higher temperature of about 1850° and 1950° F. for about 5 hours to melt the braze material and cause the braze material to bond to the substrate surface.

FIG. 4 shows another embodiment of the invention in which a tape of the same composition as previously described is used to completely fill a honeycomb structure. In this situation the tape has a thickness which is substantially equal to the height of the honeycomb cell structure and the tape is forced into the honeycomb cell structure using the previously described roller or flat pressing plate. In this situation the tape structure is used to ensure a uniform density of abradable material in each cell structure and to assure that each cell structure has a thin uniform layer of braze material at the bottom of the cell.

It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the spirit and scope of this novel concept as defined by the following claims.

I claim:

1. A method for filling a honeycomb structure comprised of a plurality of cells having a predetermined depth with an abradable material including the steps of:

a. providing a composite abradable preform consisting of a layer of powdered material containing a substantial amount of braze alloy, a second layer joined to the first layer comprising a powdered abradable composition, both of said layers also containing a binder and a plasticizer and being flexible and compliant said preform having a thickness which is less than the depth of the honeycomb cells;

b. placing said preform on the honeycomb structure to be filled with the braze containing surface adjacent the honeycomb;

c. forcing the preform into the cells and using a disposable pliable material to force the preform into the cells braze containing surface contacts the bottom of the honeycomb cells heating the filled honeycomb to remove the binder and plasticizer and further heating to melt the braze material so as to bond the abradable material to the honeycomb structure.

* * * * *

# United States Patent [19]

**Ackermann**

[11] **4,218,066**

[45] **Aug. 19, 1980**


[54] **ROTARY SEAL**


[75] Inventor: **William Ackermann**, East Hartford, Conn.

[73] Assignee: **United Technologies Corporation**, Hartford, Conn.



[21] Appl. No.: **669,424**

[22] Filed: **Mar. 23, 1976**

[51] **Int. Cl.**[3] .............................................. **F16J 15/44**

[52] **U.S. Cl.** ...................................... **277/53**; 277/215; 415/172 A; 415/174

[58] **Field of Search** .................... 277/53, 215, DIG. 6, 277/96 R, 96 B, 55, 74, DIG. 1; 415/174, 172 A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*Primary Examiner*—Richard E. Aegerter
*Attorney, Agent, or Firm*—Robert C. Walker

[57] **ABSTRACT**


Apparatus for impeding the leakage of a gaseous medium between the rotating and stationary components of a machine is disclosed. Various construction details which are specifically adapted for use in gas turbine engines are developed. Wide channel type sealing techniques are discussed in combination with honeycomb facing materials.


**16 Claims, 5 Drawing Figures**

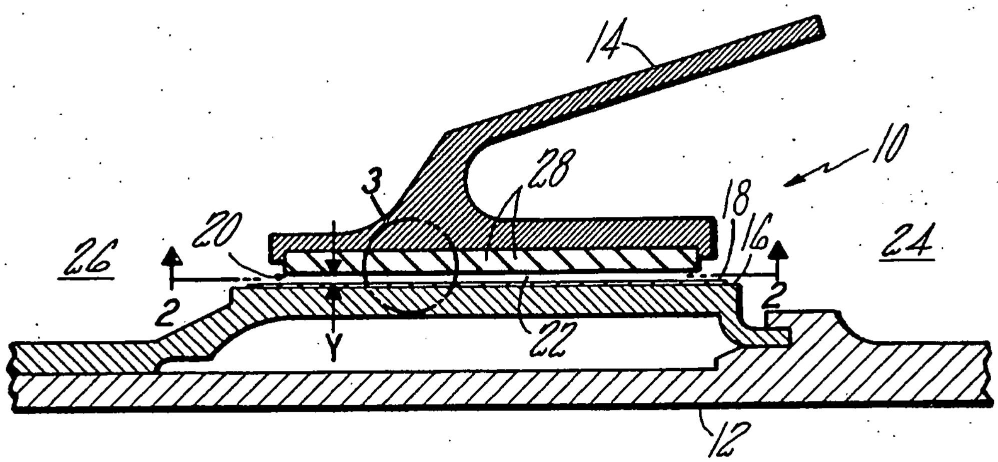


FIG. 1

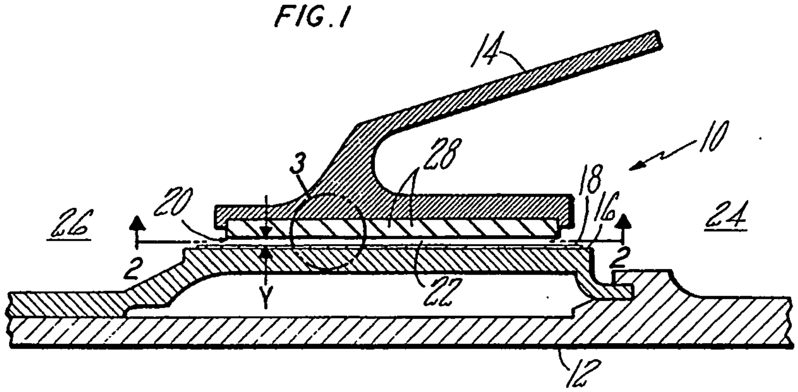



FIG. 2

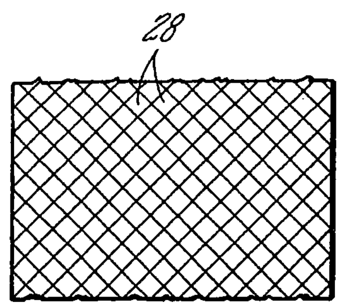



FIG. 2A

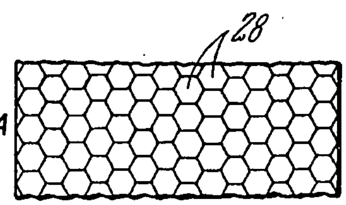



FIG. 3

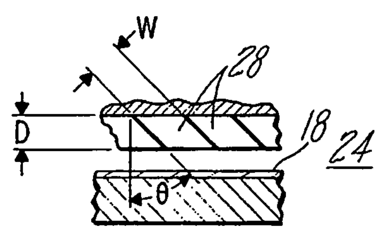
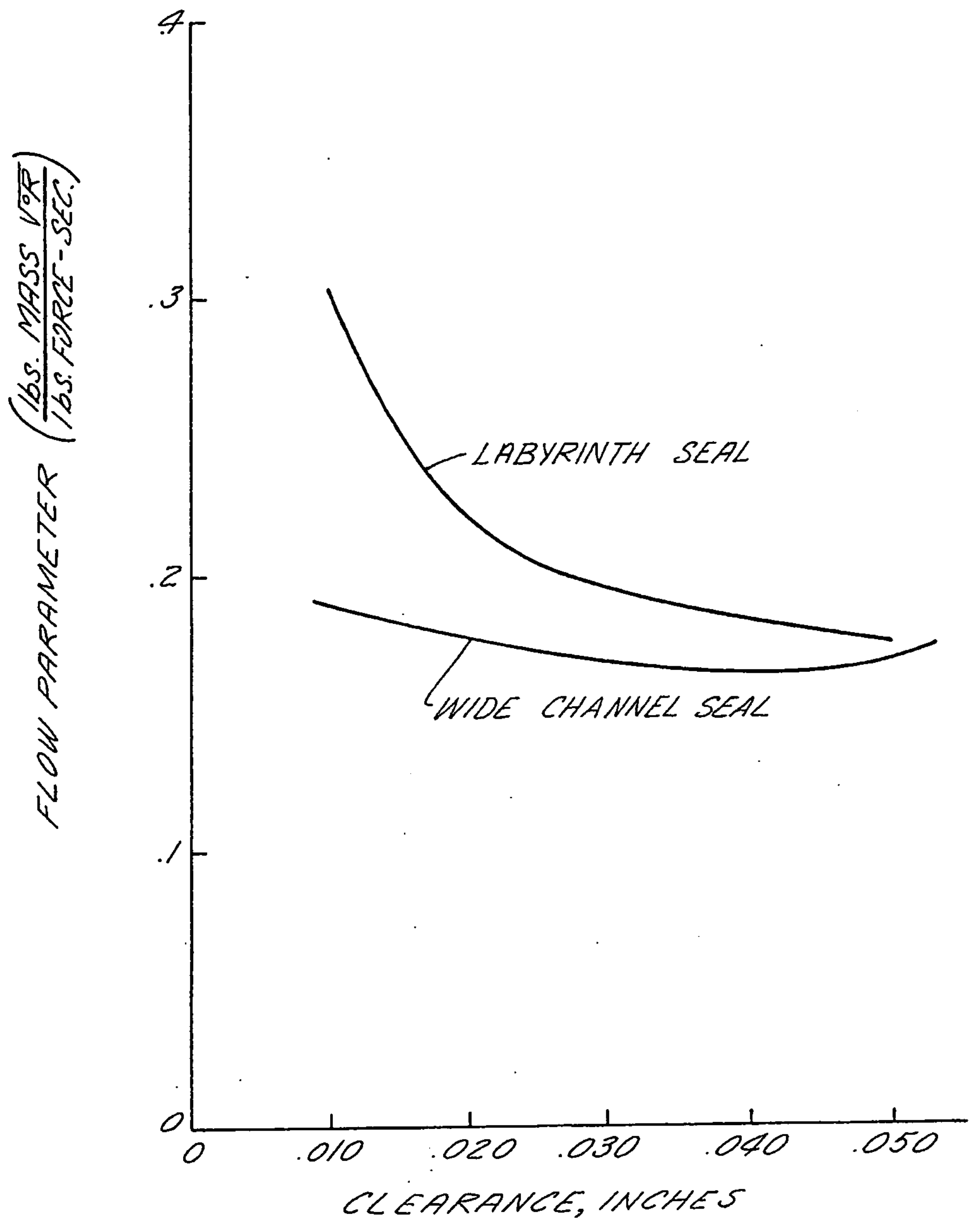


FIG. 4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.2
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FLOW PARAMETER (lbs. MASS √°R / lbs. FORCE-SEC.)
LABYRINTH SEAL
WIDE CHANNEL SEAL
0
.010
.020
.030
.040
.050
CLEARANCE, INCHES

# ROTARY SEAL

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to rotary machines and particularly to wide channel type seals between the rotating and stationary components of a machine.

2. Description of the Prior Art

Rotary seals are conventionally disposed between the rotating and stationary components of a rotary machine to impede the leakage of a fluid medium therebetween. Labyrinth seals are widely used with gaseous mediums to reduce the kinetic energy of the leakage fluid by throttling and expanding the medium. Labyrinth seals are formed of a sealing surface or land on one component and a restrictive ring on an opposing component wherein the ring projects into close proximity with the land. A plurality of restrictive rings are commonly required in series to effect sufficient energy dissipation.

In gas turbine engines labyrinth seals are typically used to prevent the excessive leakage of air into the bearing compartments and to prevent the excessive leakage of air externally of the working medium flow path from one engine stage to another. One construction for sealing between adjacent stages in the turbine section of an engine is shown in U.S. Pat. No. 3,514,112 to Pettengill entitled "Reduced Clearance Seal Construction." A plurality of restrictive rings in Pettengill project toward corresponding sealing surfaces. A throttle aperture is formed between each ring and its corresponding sealing surface. An expansion chamber is formed between each pair of adjacent rings. Air leaking through the first throttle aperture flows through the downstream chambers and apertures to establish a stable pressure differential across each ring of the labyrinth.

Labyrinth sealing is an effective technique for impeding the flow of a gaseous medium from a region of higher pressure in a gas turbine engine to a region of lower pressure at moderate clearance levels between relatively rotating components. Where a lesser clearance can be provided a second type of rotary seal, a "wide channel seal," is more effective than the labyrinth seal at an equivalent clearance. A wide channel seal is formed of two concentric cylindrical lands, one integrally mounted with the rotating component and one integrally mounted with the stationary component. The lands are closely spaced in opposing relationship to restrict the flow of the fluid medium between the two components by imposing frictional flow losses on the medium. One of the lands conventionally is covered with a honeycomb material to greatly increase flow turbulence within the channel.

Wide channel seals are less costly to manufacture and offer a weight saving when compared to labyrinth seals. Significant technical effort is being directed, therefore, to extending the clearance range of effective wide channel seals to make such seals suitable for use in engines requiring seal clearances of varied dimensions.

## SUMMARY OF THE INVENTION

A primary aim of the present invention is to minimize the leakage of a fluid medium between the rotating and stationary elements of a rotary machine. Aerodynamic resistance to flow in a seal which is effective over a varied clearance dimension is sought. In one aspect of the invention, a specific object is to provide a seal structure having low resistance to abrasion while maintaining preferred structural characteristics.



According to the present invention, a wide channel type seal between two components adapted for relative rotations is formed of a honeycomb cylindrical surface on one component and a relatively smooth cylindrical surface on the opposing component wherein the cells of the honeycomb surface are canted in the upstream direction with respect to the flow across the seal.

In accordance with one embodiment of the invention, the cylindrical surface is coated with an abrasive material to encourage abrasion without excessive local heating of the opposing honeycomb material.

A primary feature of the present invention is the wide channel type seal which is disposed between the rotating and stationary components of a rotary machine. One of the channel forming members is fabricated from a honeycomb type material in which the cells of the honeycomb are canted in the upstream direction with respect to leakage flow across the seal. In one embodiment, the opposing channel forming member is coated with an abrasive material.

A principal advantage of the present invention is improved resistance to leakage flow. Destructive interference between the relatively rotating components is avoided through the use of the low density, honeycomb material. Improved resistance to cellular deformation is found in at least one embodiment incorporating an abrasive coating on the relatively smooth, cylindrical surface. Tight clearances are employable without fear of cellular deformation as the honeycomb material abrades. Increased aerodynamic resistance to flow is imposed against the leakage medium as strong local vortices are generated in the canted cells.

The foregoing, and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of the preferred embodiment thereof as shown in the accompanying drawing.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partial sectional view taken through a wide channel seal constructed in accordance with the present invention;

FIG. 2 is a directional view taken along the line 2—2 as shown in FIG. 1;

FIG. 2A is a directional view of an alternate cell structure taken along the line 2—2 as shown;

FIG. 3 is an enlarged view of the area 3 as shown in FIG. 1; and

FIG. 4 is a graph showing comparative leakage characteristics between a labyrinth type seal and a wide channel type seal constructed in accordance with the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

A wide channel type seal **10** is shown in FIG. 1 between the relatively rotating components of a rotary machine. The seal is formed between a rotating or rotor assembly **12** and a stationary or stator assembly **14**. A cylindrical seal land **16** having an abrasive coating **18** affixed to the surface thereof is supported by the rotor **12**. A cylindrical honeycomb strip **20** is attached to the stator **14** and radially opposes the coated surface of the land **16** to form an annular channel **22** therebetween. The seal separates a region of higher pressure **24** from a

region of lower pressure 26. The honeycomb strip comprises a multiplicity of individual cells 28 which are open to the channel 22. The cells are canted in the direction of the higher pressure region 24 to an angle $\theta$ and are constructed with a cell width W as is shown in FIG. 3.

During the operation of a machine in which the wide channel seal 10 is incorporated, the pressure differential between the higher pressure region 24 and the lower pressure region 26 causes the fluid in the higher pressure region to flow through the annular channel 22. Strong local vortices are generated within each cell 28 as the fluid passes the cell openings. The vortices extend into the channel 22 to cause circumferential deflection of the flowing fluid. The circumferential deflection imposes a substantial increase in the pressure drop across the channel when compared to a seal construction confining pure axial flow.

The cells are canted into an angle $\theta$ in the direction of the higher pressure region 24. Canting the cells encourages the formation of the vortices by orienting the cell walls at an angle to the approaching flow. In one construction an angle $\theta$ of approximately forty-five degrees (45°) was found to be particularly effective although a substantial deviation on either side of forty-five degrees (45°) is expected to produce improved resistance to flow when compared to wide channel honeycomb seal structures having cells which are oriented perpendicularly to the flow through the channel.

The honeycomb cells shown in the drawing have a diamond shaped cross section as viewed in FIG. 2 from the axis of the seal. The diamond shape is representative of cell patterns in which the vortex generating cavities are staggered with respect to the flow through the channel. The staggered cell pattern increases the impending effect of each vortice over the effect that is obtainable with axially aligned vortices. Other staggered geometrics such as one employing the hexagonal cross section of FIG. 2A are correspondingly effective. The concepts disclosed herein, however, are not exclusively limited to staggered geometrics.

Tight clearance control between the relatively rotating components of a machine is obtainable with apparatus constructed in accordance with the concepts taught herein. The honeycomb structure has a very low density and is abradable during operation of the machine. The initial channel width Y, as shown in FIG. 1, is set at less than the expected relative radial excursion of the rotor 12 so that at the condition of maximum excursion the seal land 16 abrades the outer portion of the honeycomb strip 20 to provide a zero (0) clearance at maximum rotor excursion.

Damage to the honeycomb structure during interference between the strip 20 and the land 16 is minimized on one construction wherein the abrasive coating 18 is affixed to the inwardly facing surface of the land 16. The abrasive coating severs the interfering honeycomb from the remaining structure to avoid the deformation of material into the cell openings and the resultant decrease in the strength of the vortices generated by the deformed structure. Silicon carbide and aluminum oxide have been found to be effective abrasive materials, although, other coatings having similar qualities are expected to produce comparable results.

The depth D of the individual cells is optimized for each cell width W to provide a structure which generates strong local vortices. For a cell width of one quarter (¼) of an inch, a depth of approximately one hundred thousandths (0.100) of an inch is effective. For a cell width of one eighth (⅛) of an inch, a depth of approximately sixty thousandths (0.060) of an inch is effective.

The FIG. 4 graph demonstrates the decreased leakage rate of a honeycomb wide channel type seal having cells canted in accordance with the present invention when compared to a honeycomb land labyrinth type seal having four restrictive rings. Both seals have an overall axial length of two (2) inches and separate regions having a pressure ratio of 1.5 therebetween. As is discernible from the graph, the wide channel seal exhibits dramatically improved sealing effectiveness at clearances less than fifty thousandths (0.050) of an inch.

Although the invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that various changes and omissions in the form and detail thereof may be made therein without departing from the spirit and the scope of the invention.

Having thus described a typical embodiment of my invention, that which I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination with the rotor and stator assemblies of a rotary machine, a seal structure for impeding the leakage of a gaseous medium between said assemblies wherein said structure comprises a cylindrical seal land extending from the rotor assembly and a cylindrical honeycomb faced land extending from the stator assembly into close proximity with the seal land of the rotor assembly forming, therewith, an annular channel separating the rotor and stator assemblies of the machine, said honeycomb material having a multiplicity of cells which are canted in the upstream direction with respect to the anticipated direction of flow through the channel during operation of the machine to encourage the generation of local vortices within the channel for impeding said leakage of gaseous medium between the rotor and stator assemblies.

2. The invention according to claim 1 wherein the cells of the honeycomb material are canted to an angle of forty-five degrees (45°) with respect to said anticipated direction of flow.

3. The invention according to claim 1 wherein said seal land of the rotor assembly has a relatively smooth cylindrical surface.

4. The invention according to claim 1 wherein said formed annular channel has an axial length of approximately two inches.

5. The invention according to claim 1 wherein said cells of the honeycomb material have a depth of approximately one hundred thousandths (0.100) of an inch and a cell width of approximately two hundred fifty thousandths (0.250) of an inch.

6. The invention according to claim 1 wherein said cells of the honeycomb material have a depth of approximately sixty thousandths (0.060) of an inch and a cell width of approximately one hundred twenty-five thousandths (0.125) of an inch.

7. The invention according to claim 1 wherein said cells of the honeycomb material have a diamond shape.

8. The invention according to claim 1 wherein said cells of the honeycomb material have a hexagonal shape.

9. The invention according to claim 1 wherein said seal land has affixed thereto an abrasive coating which is adapted to wear the honeycomb land upon interference rather than deform the honeycomb cellular structure.

10. The invention according to claim 9 wherein said abrasive coating includes silicon carbide.

11. The invention according to claim 9 wherein said abrasive coating includes aluminum oxide.

12. A seal structure for impeding the leakage of a gaseous medium within a turbine engine from a region of higher pressure to a region of lower pressure, comprising:

a first cylindrical seal land; and

a second cylindrical seal land which radially opposes said first land forming an annular channel therebetween which axially separates the region of higher pressure from the region of lower pressure, and wherein the second land has affixed thereto a honeycomb material so oriented as to cant the cells of the honeycomb material in the direction of the higher pressure region.



13. The invention according to claim 12 wherein the cells of the honeycomb material have a diamond shaped cross section including a cell width of approximately one quarter (¼) of an inch and a cell depth of approximately one tenth (1/10) of an inch and wherein the cells are canted to an angle of approximately forty-five degrees (45°) in the direction of the higher pressure region.

14. The invention according to claim 12 wherein said seal land has affixed thereto an abrasive coating which is adapted to wear the honeycomb land upon interference rather than deform the honeycomb cellular structure.

15. The invention according to claim 14 wherein said abrasive coating includes silicon carbide.

16. The invention according to claim 14 wherein said abrasive coating includes aluminum oxide.

* * * * *

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
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Washington, D.C. 20231

sjc

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | | ATTORNEY DOCKET NO. |
|---|---|---|---|---|
| 08/327,744 | 10/24/94 | STONE | M | 3309P-65 |

QM12/0815

J. KEVIN GROGAN
MCCORMICK, PAULDING & HUBER, LLP
CITY PLACE II
158 ASYLUM STREET
HARTFORD CT 06103-4102

| EXAMINER | |
|---|---|
| GOODMAN, C | |
| **ART UNIT** | **PAPER NUMBER** |
| 3724 | 25 |

DATE MAILED: 08/15/00

**Please find below and/or attached an Office communication concerning this application or proceeding.**

**Commissioner of Patents and Trademarks**

DOCKET JKG
FILE 3309P-65
FOR [illegible] 10/15/00
DATE 8/22/00 BY [illegible]

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AUG 21 2000
McCormick, Paulding & Huber

EXHIBIT
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OIPE JC136 JAN 1 3 2004 PATENT & TRADEMARK OFFICE

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 08/327,744 | STONE ET AL. | |
| | Examiner | Art Unit | |
| | Charles Goodman | 3724 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136 (a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).

**Status**

1)☒ Responsive to communication(s) filed on *23 October 1998* .

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-8* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-8* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claims _____ are subject to restriction and/or election requirement.

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**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are objected to by the Examiner.

11)☐ The proposed drawing correction filed on _____ is: a)☐ approved b)☐ disapproved.

12)☐ The oath or declaration is objected to by the Examiner.

**Priority under 35 U.S.C. § 119**

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d).

a)☐ All b)☐ Some * c)☐ None of the CERTIFIED copies of the priority documents have been:

1.☐ received.

2.☐ received in Application No. (Series Code / Serial Number) _____ .

3.☐ received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14)☐ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. & 119(e).

**Attachment(s)**

15) ☐ Notice of References Cited (PTO-892)
16) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
17) ☐ Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____ .
18) ☐ Interview Summary (PTO-413) Paper No(s). _____ .
19) ☐ Notice of Informal Patent Application (PTO-152)
20) ☐ Other:

## DETAILED ACTION

1. In view of the Appeal Brief filed on October 23, 1998, PROSECUTION IS HEREBY REOPENED. New grounds of rejection are set forth below.

To avoid abandonment of the application, appellant must exercise one of the following two options:

(a) file a reply under 37 CFR 1.111 (if this Office action is non-final) or a reply under 37 CFR 1.113 (if this Office action is final); or,

(b) request reinstatement of the appeal.

If reinstatement of the appeal is requested, such request must be accompanied by a supplemental appeal brief, but no new amendments, affidavits (37 CFR 1.130, 1.131 or 1.132) or other evidence are permitted. See 37 CFR 1.193(b)(2).

2. The After Final Amendment filed on October 22, 1996 has been entered, since this amendment has been approved entry for Appeal purposes in the Advisory Action, Paper No. 13.

### *Claim Rejections - 35 USC § 103*

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any

evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

5. Claims 1-8 are rejected under 35 U.S.C. 103(a) as being unpatentable over McComas in view of Shiembob, Ryan, or Ackerman.

McComas discloses the invention substantially as claimed including the inherent step of having the liquid stream striking the substrate at the base of the coating 1 (analogous to the claimed honeycomb) due to, *inter alia*, the relative motion between the component and the liquid stream 5 and the fact that McComas removes both the coating and the bond coating 2 (analogous to the claimed braze) *simultaneously*. See Figs. 1-1A, c. 1, l. 19 - c. 3, l. 66. Although McComas lacks a honeycomb as the form of the coating, McComas does teach that the method encompasses removal of *abradable seals* which are used in gas turbine engines. See *Id.*, c. 1, ll. 19-25. Regarding the honeycomb, Shiembob, Ryan, and Ackerman all teach that a honeycomb, braze, and substrate is a well known abradable seal in the art for gas turbine engines. More specifically, Shiembob teaches an insulated honeycomb seal for gas turbine engines comprising a honeycomb 2 that is inherently brazed onto a substrate 18. See whole patent. Ryan teaches another abradable seal for gas turbine engines comprising a honeycomb 2 brazed onto a substrate 1. See whole patent. Ackerman teaches a further example of an abradable seal comprising a honeycomb 28 which is inherently brazed onto a substrate (not designated by reference but see Fig. 1). See whole patent. Thus, it would have been obvious to the ordinary artisan at the time of the instant invention to provide the method of McComas with the honeycomb as taught by

either Shiembob, Ryan, or Ackerman in order to facilitate the removal of the same from the substrate during maintenance, since as noted above, the honeycomb is another form of an abradable seal that is a "coating" for which McComas method is to be applied.

6. Claims 1-8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shiembob, Ryan, or Ackerman in view of McComas.

Shiembob, Ryan, or Ackerman all disclose various forms of abradable seals for gas turbine engine comprising a honeycomb, braze, and substrate structure. See *Id.* However, none of these references teach the method of removal of the honeycomb and braze from the substrate. In that regard, McComas teaches that it is common practice in the art to perform routine engine maintenance which frequently requires removal of coatings in the abradable seals. See *Id.*, c. 1, ll. 60-67. McComas specifically teaches a method of removing a coating 1 and bond coating 2 that is an abradable seal from a substrate comprising all the method steps claimed, i.e. flow, pressure, and angle of the liquid stream 5, including the inherent step of having the liquid stream striking the substrate at the base of the coating, since, *inter alia*, this striking position is the obvious position that facilitates simultaneous removal of the coating and bond coating from the substrate, this method facilitating easy removal without damaging the substrate. Thus, it would have been obvious to the ordinary artisan at the time of the instant invention to apply the liquid removal method of McComas to the abradable honeycomb seals of either Shiembob, Ryan, or Ackerman in order to facilitate easy removal of the honeycomb and braze without damaging the substrate whenever maintenance requires the same, since as taught by McComas, abradable seals is just another form of coating that is subject to removal of the same during maintenance.

*Response to Arguments*

7. Applicant's arguments with respect to claims 1-8 have been considered but are moot in view of the new ground(s) of rejection.

*Conclusion*

8. Applicant's submission of an information disclosure statement under 37 CFR 1.97(c) with the fee set forth in 37 CFR 1.17(p) on May 21, 1996 (Paper No. 9) prompted the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 609(B)(2)(i). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

9. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Charles Goodman whose telephone number is (703) 308-0501. The examiner can normally be reached on Monday-Thursday between 7:30 AM to 6:00 PM

EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Rinaldi Rada, can be reached on (703) 308-2187. The fax phone number for this Group is (703) 305-3579.

Communications via Internet e-mail regarding this application, other than those under 35 U.S.C. 132 or which otherwise require a signature, may be used by the applicant and should be addressed to [**rinaldi.rada@uspto.gov**].

All Internet e-mail communications will be made of record in the application file. PTO employees do not engage in Internet communications where there exists a possibility that sensitive information could be identified or exchanged unless the record includes a properly signed express waiver of the confidentiality requirements of 35 U.S.C. 122. This is more clearly set forth in the Interim Internet Usage Policy published in the Official Gazette of the Patent and Trademark on February 25, 1997 at 1195 OG 89.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the Group receptionist whose telephone number is (703) 308-1148.

Charles Goodman

**Charles Goodman**
**Patent Examiner**
**AU 3724**

cg CG
August 10, 2000

Rinaldi I. Rada
Supervisory Patent Examiner
Group 3700

The opinion in support of the decision being entered today was **not** written for publication and is **not** binding precedent of the Board.

Paper No. 39



UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

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Ex parte M. ANTHONY STONE, DARCY J. HARBAUGH,
and CLIFFORD V. MITCHELL

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Appeal No. 2002-1033
Application No. 08/327,744

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HEARD: JANUARY 14, 2003

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Before COHEN, ABRAMS, and FRANKFORT, Administrative Patent Judges.

COHEN, Administrative Patent Judge.

## DECISION ON APPEAL

This is an appeal from the final rejection of claims 1 through 8, all of the claims in the application.

Appellants' invention pertains to a method for removing honeycomb and braze from a substrate. A basic understanding of the invention can be derived from a reading of exemplary claim 1, a copy of which appears as EXHIBIT C attached to the main brief (Paper No. 30).

As evidence of obviousness, the examiner has applied the documents listed below:

| | | |
|---|---|---|
| Ackermann | 4,218,066 | Aug. 19, 1980 |
| Ryan | 4,409,054 | Oct. 11, 1983 |
| Shiembob | 4,433,845 | Feb. 28, 1984 |
| McComas et al (McComas) | 5,167,721 | Dec. 1, 1992 |

The following rejections are before us for review.

Claims 1 through 8 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over McComas in view of Shiembob, Ryan, or Ackermann.

Claims 1 through 8 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Shiembob, Ryan, or Ackermann in view of McComas.

The full text of the examiner's rejections and response to the argument presented by appellants appears in the answer (Paper No. 32), while the complete statement of appellants' argument can be found in the main and reply briefs (Paper Nos. 30 and 35).

OPINION

In reaching our conclusion on the issues raised in this appeal, this panel of the Board has carefully considered appellants' specification and claims, the applied teachings,[1] the declaration of Clifford V. Mitchell (EXHIBIT E attached to main brief), and the respective viewpoints of appellants and the examiner. As a consequence of our review, we make the determination which follows.

We do not sustain the respective rejections of appellants' claims under 35 U.S.C. § 103(a), for the reasons addressed below.

Independent claim 1 is drawn to a method for removing honeycomb and braze from a substrate, said honeycomb having a base and a ribbon direction, comprising, inter alia, a liquid

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[1] In our evaluation of the applied prior art, we have considered all of the disclosure of each document for what it would have fairly taught one of ordinary skill in the art. See In re Boe, 355 F.2d 961, 965, 148 USPQ 507, 510 (CCPA 1966). Additionally, this panel of the board has taken into account not only the specific teachings, but also the inferences which one skilled in the art would reasonably have been expected to draw from the disclosure. See In re Preda, 401 F.2d 825, 826, 159 USPQ 342, 344 (CCPA 1968).

stream striking the substrate at the base of the honeycomb, thereby removing the honeycomb and braze from the substrate.

At the outset, we note that the examiner has clearly expounded the basis for each rejection on appeal, and thoroughly addressed the arguments of appellants in the answer. However, for the reasons set forth, infra, the rejections cannot be sustained.

From our perspective, the combined teachings of the applied prior art, understood in light of the acknowledged background in the art (appellants' specification, page 1), would have been suggestive to one having ordinary skill of removing honeycomb and braze from a substrate by directing a liquid stream at the top of the honeycomb until the braze is exposed. The motivation for practicing the latter method would have been the teaching of McComas, in particular, in explicitly revealing liquid jet erosion as a viable alternative that does not result in substrate damage, the consequence of other known removal techniques. The deficiency, however, in the rejections before us is clearly seen to be the lack of any suggestion in the applied prior art teachings for the claimed recitation of a liquid stream "striking

the substrate at the base of the honeycomb." The examiner's attempt (answer, pages 21 through 24) to overcome the noted deficiency by reliance upon the skill in the art simply does not provide a sound evidentiary basis for concluding that appellants' claimed method would have been obvious. In other words, only appellants' disclosure, and not the applied prior art before us, teaches and would have been suggestive of a liquid stream striking a substrate at the base of honeycomb, as now claimed.

## REMAND TO THE EXAMINER

We remand this application to the examiner to consider the patentability of the claimed subject matter under 35 U.S.C. § 103 based upon the acknowledged prior art (appellant's specification, page 1) or like patents in view of the McComas patent and, for example, a patent to Carr.[2] Carr (Fig. 2) appears to teach an alternative optimal path of media flow in the art (column 4, lines 55 through 66).

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[2] U.S. Patent No. 4,731,125, issued Mar. 15, 1988, and of record in the application.

In summary, this panel of the Board has not sustained the rejections on appeal. Further, we have remanded the application to the examiner to review the matter discussed above.

The decision of the examiner is reversed.

REVERSED AND REMANDED

| | | |
|---|---|---|
| IRWIN CHARLES COHEN<br>Administrative Patent Judge | ) | |
| NEAL E. ABRAMS<br>Administrative Patent Judge | ) | BOARD OF PATENT<br>APPEALS<br>AND<br>INTERFERENCES |
| Charles E. Frankfort<br>CHARLES E. FRANKFORT<br>Administrative Patent Judge | ) | |

ICC/lbg